Controlled Cold Water and Water Slushy Ingestion, and Heat Performance in Subjects of Average Fitness

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INTRODUCTION

It is a well known conception that endurance performance capacity of an athlete is hindered in hot environments, and leads to an early onset of fatigue[1]. Due to the heat, and dehydration if fluids aren't ingested, core temperature rises, thermoregulation is impaired, and the cardiovascular, metabolic and nervous system functions are depressed; all of which negatively affect one's ability to perform physical work.[2] However, fluid ingestion is known to improve exercise performance by maintaining these systems' functions, and can lead to a reduction of core body temperature[1], through a proposed heat sink effect, if cold enough.[5] While research has been conducted on the influence of hydration on exercise performance, little research has been done which consider the beverages' temperature during controlled consumption.[1] More specifically, the effects of cold water (4°C), water slushy (-1°C) and room temperature water (22°C) on heat performance have not been compared directly.[3] Most research that has been completed uses a range of four different temperatures[4] including a thermoneutral beverage (37°C) as a control rather than a practical room temperature control.[5] In addition, most of the research that included water slushy as a treatment used a carbohydrate-electrolyte solution rather than pure water.[3] Also, most of the research used *ad libitum* consumption rather than controlled consumption (volume relative to body mass).[5] Finally, while the effect of endurance performance in the heat has been completed on healthy male cyclists at a professional level, there is no evidence found of the effect of beverage temperature on endurance performance in the heat on males of average fitness.[3]

PURPOSE

The purpose of the study was to examine the effect of controlled consumption of water at different temperatures on heat performance in subjects of average fitness.

METHODS

IRB Approval. The study was approved by the Institutional Review Board (Human Subjects) at Texas A&M University-Kingsville.

Subjects. All subjects were provided informed consent prior to testing. Fifteen male subjects (*N*=15) were recruited from the student population at Texas A&M University-Kingsville.

Pre-participation Screening/Testing. All subjects underwent a health screening according to the American College of Sports Medicine's guidelines for exercise testing and prescription.[6] Only subjects classified as low for untoward events during exercise based on these guidelines were allowed to participate. Additionally, only those who were classified as physically active and had no prior history or heat illness/injury were allowed to participate in the study. Tests for body composition (mass, stature, percent body fat from skinfolds) and peak oxygen consumption (via open circuit spirometry, modified Astrand cycle protocol [7]) were also conducted. Subjects were given instructions on how to report for each experimental trial, including specific pre-trial diet and hydration instructions.

Experimental Design. A balanced cross-over design was used. Each subject underwent three experimental trials [cold water (4°C) treatment (CD), water slushy (-1°C) treatment (SL), and room temperature water (22°C) treatment (RM)] on separate days one week apart. During the three trials, the subjects were required to exercise on a stationary rate independent cycle ergometer at an intensity equal to 70% of their peak oxygen consumption rate (i.e., vigorous exercise) in the heat (34.0 ± 0.6°C, 41.7 ± 2.7% relative humidity, 3.6 km·hr^{-1} wind speed). Subjects were asked to perform each exercise bout until volitional maximum. During each trial, subjects were required to consume a controlled volume (2.5 g·$kg_{BodyMass}^{-1}$) of one of the fluids (CD, SL or RM) every 10 minutes.

Measurements. During each experimental trial, the following measurements were made:

Maximal Exercise Time (min) – Subjects were instructed to performed the exercise bout until they could no longer go on (volitional maximum). Subjects were blinded to the measurement of exercise time for use as a dependent variable.

Change in Exercise Core Body Temperature (Δ°C) – Pre-and post-exercise core body temperature were measured using a digital tympanic thermometer and the change in core temperature was calculated.

Exercise Sweat Rate (ml·hr^{-1}) – Pre- and post- exercise dry nude body mass were measured. The change in body mass and the volume of fluid consumed during the trial was used to calculate sweat rate.

Exercise Heart Rate (beat·min^{-1}) – Heart rate was monitored continuously throughout each exercise bout via telemetry, and recorded after every fluid feeding (10 min) and at the point of volitional test termination.

METHODS, cont.

Measurements, cont.

Exercise Mean Skin Temperature (°C) – Skin surface temperature at the left triceps, chest, forearm, thigh, and calf was monitored throughout the exercise bouts through a hard wired physiological data acquisition system. Mean skin temperature (°C) was calculated from these 5 readings after every fluid feeding (10 min) and at the point of volitional test termination using the following formula[8]: MT_{sk} = (0.22 x calf) + (0.28 x thigh) + (0.28 x chest) + (0.14 x forearm) + (0.08 x triceps).

Exercise Rating of Perceived Exertion (0-10) – Subjects were asked to rate their perceived exertion (RPE) during the exercise bout using the Borg Category-Ratio Scale.[9] RPE was recorded after every fluid feeding (10 min) and at the point of volitional test termination. Subjects were blinded to the use of RPE as a dependent variable.

Statistical Analysis. One-way (beverage) ANOVA with repeated measures was used to analyze for differences between trials (CD, SL, RM) in: maximal exercise time, pre-/post-change in core temperature, sweat rate, as well as heart rate, mean skin temperature, and RPE at volitional maximum. Two-way (beverage x time) ANOVA with repeated measures was used to analyze for differences between trials (CD, SL, RM) and across common time points for all subjects (10 min, 20 min) in: heart rate, mean skin temperature, and RPE. If needed, appropriate *post-hoc* tests were used to make all pairwise comparisons for specific differences across the three experimental trials or time points. The experimentwise error rate (α=0.05) was maintained throughout all *post-hoc* tests for specific differences.

RESULTS

Table 1: Subject Demographics

Variable	Mean	SD	Range
Age (yr)	23.0	2.3	19.9-29.1
Body Mass (kg)	84.3	21.3	57.2-132.7
Body Stature (cm)	176.4	6.9	169.6-191.8
Body Fat (%)	10.9	4.9	4.7-21.7
VO_{2Peak} (ml·kg^{-1}·min^{-1})	37.8	8.8	25.1-60.0
70% VO_{2Peak} Work Rate (W)	140.8	22.8	104.0-182.0

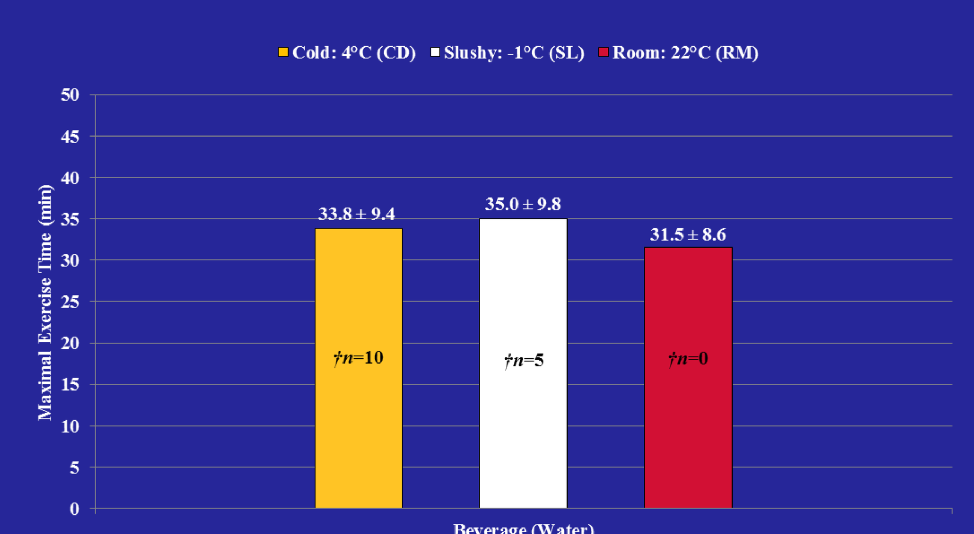

Figure 1: Beverage effect on exercise time to volitional maximum. While exercise time did not differ significantly between treatments, a trend (*p*=0.0680) was noted where SL and CD > RM, which was supported by all of subjects having their longest exercise time during the CD or SL trials (denoted by †).

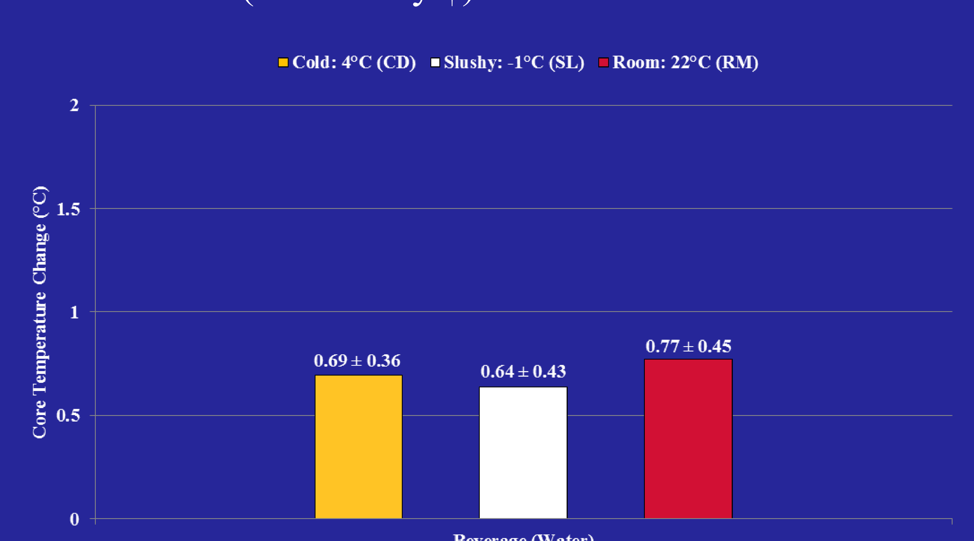

Figure 2: Beverage effect on change in core temperature. Core temperature change from pre- to post-exercise did not differ significantly between the treatments (*p*=0.2120).

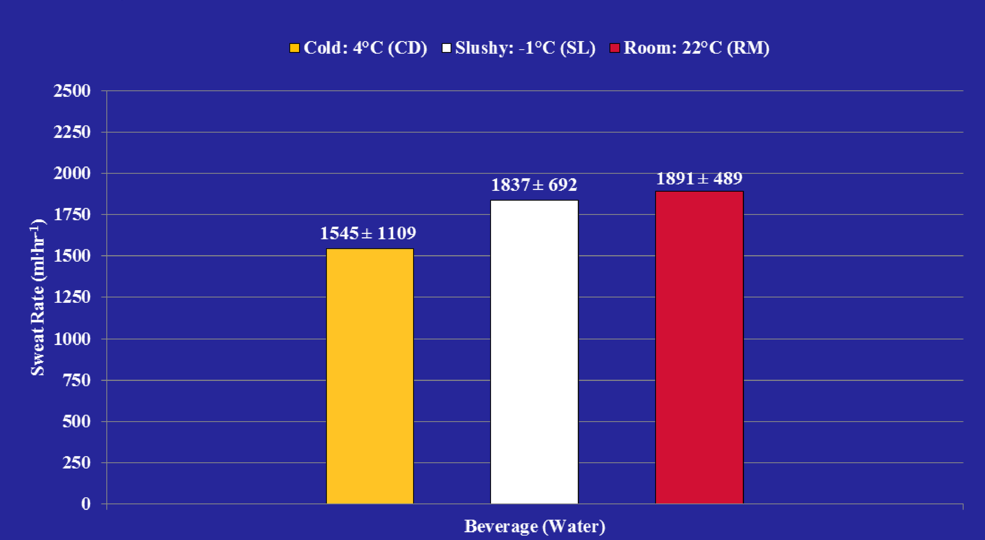

Figure 3: Beverage effect on sweat rate. Sweat rate did not differ significantly between the treatments (*p*=0.3730).

RESULTS, cont.

Table 2: Beverage Main Effect for Heart Rate, Mean Skin Temperature, and RPE

Variable	Cold 4°C (CD)	Slushy -1°C (SL)	Room 22°C (RM)
Heart Rate (beat·min^{-1})	157 ± 16	153 ± 18*	160 ± 17*
Mean Skin Temperature (°C)	36.1 ± 0.4	36.0 ± 0.4	36.2 ± 0.3
RPE (0-10)	4.2 ± 1.5	4.5 ± 2.0	4.8 ± 1.9

When pooled across time, a main effect for beverage was seen in heart rate (*p*=0.0007) where SL<RM (*). No significant differences in mean skin temperature (*p*=0.1470) or RPE (*p*=0.1240) between beverage treatments when pooled across time were found.

Table 3: Time Main Effect for Heart Rate, Mean Skin Temperature, and RPE

Variable	10 min	20 min
Heart Rate (beat·min^{-1})	153 ± 16*	161 ± 18*
Mean Skin Temperature (°C)	35.9 ± 0.3**	36.2 ± 0.3**
RPE (0-10)	3.3 ± 1.4***	5.8 ± 2.1***

When pooled across beverage, a main effect for time (*p*<0.0001) was seen in heart rate (*), mean skin temperature (**) , and RPE (***) where T20>T10 for each.

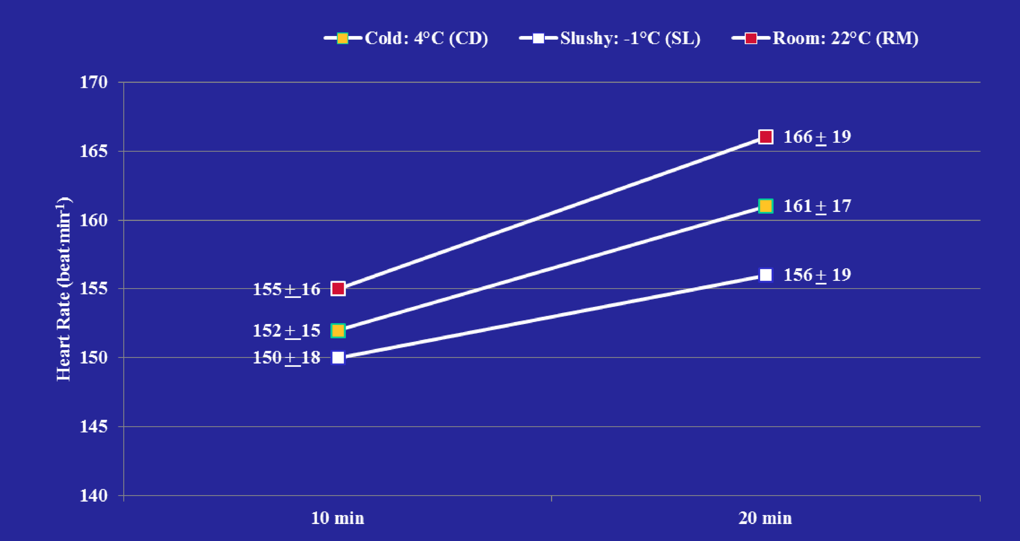

Figure 4: Beverage x Time Interaction for Heart Rate, Mean Skin Temperature, and RPE. A trend towards a significant beverage x time interaction was seen for heart rate (*p*=0.0900)(see Figure 4), but CD, SL and RM did not respond differently over time for mean skin temperature (*p*=0.6900) or RPE (*p*=0.3960).

Table 4: Heart Rate, Mean Skin Temperature, and RPE at Volitional Maximum

Variable	Cold 4°C (CD)	Slushy -1°C (SL)	Room 22°C (RM)
Heart Rate (beat·min^{-1})	168 ± 20	165 ± 20*	173 ± 20*
Mean Skin Temperature (°C)	36.3 ± 0.5	36.1 ± 0.4	36.4 ± 0.3
RPE (0-10)	8.8 ± 1.3	8.9 ± 1.4	8.7 ± 1.5

Heart rate at volitional maximum differed between beverage treatments (*p*=0.0170), specifically SL<RM (*), but there was no difference between mean skin temperature (*p*=0.1400) or RPE (*p*=0.8280) at volitional maximum.

CONCLUSIONS

While mean skin temperature, sweat rate and RPE did not differ between treatments, the results of this study suggest that overall, the SL treatment did appear to show a slight performance improvement over the practical control (RM) in respect to exercise time to volitional maximum (trend), but not necessarily over the CD treatment. Supporting this, all of the subjects had their longest bout with either the SL or CD treatment but most had it with the CD treatment. Also, a lower heart rate at volitional maximum was seen in the SL over RM but not CD, and a trend where heart rate appeared to rise differently over time in RM than in both SL and CD was seen. The results could suggest that there may be a potential point where a colder beverage temperature does not necessarily yield a greater heat sink effect, or these results could have been caused due to an insufficient amount of time during the exercise bout by the subjects. Regardless, the information is useful for subjects of average fitness who will tend to exercise for a shorter amount of time. It should also be noted that most subjects had a hard time consuming the water slushy, which should be addressed in additional studies. Further investigation using larger sample sizes is warranted to examine the effects of fluid temperature and ice slushy on performance in the heat.

REFERENCES

1. Burdon, C., O'Connor, H., Gifford, J., & Shirreffs, S. (2013). Influence of beverage temperature on exercise performance in the heat: A systematic review. *International Journal of Sport Nutrition and Exercise Metabolism, 20*(2), 166-174.
2. Lafata, D., Carlson-Phillips, A., Sims, S., & Russell, E. (2012). The effect of a cold beverage during an exercise session combining both strength and energy systems development training on core temperature and markers of performance. *Journal of the International Society of Sports Nutrition, 9*, 44-51.
3. Burdon, C., O'Connor, H., Gifford, J., Shirreffs, S., Chapman, P., & Johnson, N. (2010). Effect of drink temperature on core temperature and endurance cycling performance in warm, humid conditions. *Journal of Sports Sciences*, *28*(11), 1147-1156.
4. Hosseinlou, A., Khamnei, S., & Zamanlu, M. (2013). The effect of water temperature and voluntary drinking on the post rehydration sweating. *International Journal of Clinical and Experimental Medicine*, *6*(8), 683-687.
5. Burdon, C., Hoon, M., Johnson, N., Chapman, P., & O'Connor, H. (2013). The effect of ice slushy ingestion and mouthwash on thermoregulation and endurance performance in the heat. *International Journal of Sport Nutrition and Exercise Metabolism, 23*, 458-469.
6. American College of Sports Medicine. (2014). *ACSM's guidelines for exercise testing and prescription* (9th ed.). Philadelphia: Lippincott, Williams & Wilkins.
7. Artrand, P.O. (1965). *Work tests with the bicycle ergometer.* Varberg, Sweden: AB Cykelfabriken Monark.
8. Toner, M.M., Sawka, M.N., Holden, W.L., & Pandolf, K.B. (1985). Comparison of thermal responses between rest and leg exercise in water. *Journal of Applied Physiology*, *59*¸248-253.
9. Borg, G.A. (1982) Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, *14*, 377-381.

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