Hunt, Andrew P., Feigl, Beatrix, & Stewart, Ian B. (2012) The intraocular pressure response to dehydration : a pilot study. *European Journal of Applied Physiology*, *112*(5), pp. 1963-1966.

http://dx.doi.org/10.1007/s00421-011-2143-5

Title:

The intraocular pressure response to dehydration: A pilot study

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Abstract

The aim of this study was to determine the intraocular pressure response to differing levels of dehydration. Seven males participated in 90 min of treadmill walking (5 km·h^{-1} and 1% grade) in both temperate (22°C) and hot (43°C) conditions. At baseline and 30 min intervals intraocular pressure, nude body mass, body temperature and heart rate were recorded. Statistically significant interactions ($p < 0.05$) were observed for intraocular pressure (hot condition: baseline 17.0 ±2.9, 30 min 15.6 ±3.5, 60 min 14.5 ±3.7, and 90 min 13.6 ±2.9 mmHg; temperate condition: baseline 16.8 ±2.7, 30 min 16.5 ±2.6, 60 min 15.8 ±2.5, and 90 min 15.7 ±1.8 mmHg) and body mass loss (hot condition: 30 min -1.07 ±0.35, 60 min -2.17 ±0.55, and 90 min -3.13 ±0.74%; temperate condition: 30 min -0.15 ±0.11, 60 min -0.47 ±0.18, and 90 min -0.78 ±0.25%). Significant linear regressions ($p < 0.05$) were observed for intraocular pressure and body mass loss (adjusted $r^2 = 0.24$), and intraocular pressure change and body mass loss (adjusted $r^2 = 0.51$). In conclusion, intraocular pressure was progressively reduced during a period of exercise causing dehydration, but remained relatively stable when hydration was maintained. The present study revealed a moderate relationship between dehydration (body mass loss) and intraocular pressure change.

Keywords:

Body Mass Loss, Hypohydration, Hydration Assessment.

Introduction

Dehydration reduces exercise performance (Cheuvront et al. 2005), elevates body temperature (Armstrong et al. 1997), and increases the risk of heat illness (Donoghue et al. 2000). A novel approach to the assessment of hydration status could be found in the measurement of intraocular pressure (the pressure within the eye) using a handheld device (Abraham et al. 2006). Studies of the intraocular pressure response to short duration and high intensity dynamic exercise have observed a decline in intraocular pressure to coincide with a rise in blood lactate and plasma osmolality (Marcus et al. 1970). It has been proposed that the rise in plasma osmolality creates an osmotic disequilibrium between aqueous humor and plasma, favouring the movement of water from the aqueous humor to the blood (Risner et al. 2009). This reduces the rate of aqueous humor formation and lowers intraocular pressure.

Whilst high intensity exercise will cause hyperosmolality of the blood to occur rapidly, low intensity exercise in a hot environment can lead to dehydration, which also raises plasma osmolality (Popowski et al. 2001). Several researchers have suggested that dehydration causing an increase in plasma osmolality (as opposed to acidosis from high intensity exercise) could also lower the rate of aqueous formation and reduce intraocular pressure (Harris et al. 1994). However, this study did not require subjects to exercise for a sufficient duration, or in a hot environment, to expect a decline in hydration status. Therefore, the aim of this investigation was to determine if the intraocular pressure response during exercise with fluid restriction differs in a temperate or hot climate; promoting differing levels of dehydration. It was hypothesised that intraocular pressure would be lowered to a greater extent during exercise in the heat, concomitant with the greater dehydration experienced.

Methods

Seven males (age: 33.3 ± 9.6 years, height: 175 ± 0.06 cm, body mass: 68.6 ± 8.1 kg, maximal aerobic power: 59.7 ± 7.2 $mL \cdot kg^{-1} \cdot min^{-1}$, and un-acclimatised) with normal ocular health as confirmed by an ophthalmologist (BF) volunteered to participate. Participants were informed of the requirements of the study prior to signing a consent form. This study received ethical approval from the Queensland University of Technology Human Research Ethics Committee.

Participants were required to attend three testing sessions. The first session involved the determination of maximal aerobic power by an incremental treadmill running test to exhaustion. The remaining two sessions involved 90 min walking trials. Commencing at 8:30am, the walking trials were conducted in a hot (42.8 ± 0.8˚C ambient temperature and 34.2 ± 3.4% relative humidity) and temperate climate (21.8 ± 0.7˚C ambient temperature and 51.0 ± 2.0% relative humidity), presented in a random order. Participants avoided heavy exercise and consuming alcohol, caffeine and tobacco in the 24 hours prior, and consumed no food from midnight until after the trial. To ensure adequate pre-trial hydration, all participants were provided with 30 $mL \cdot kg^{-1}$ body mass of an isotonic solution (Gatorade) to drink between 4 and 10 pm the night before. Participants were instructed to consume a further 250 mL of this solution upon rising, and no later than 60 min before the trial. Following this no fluid was consumed until after the trial was completed. Pre-trial hydration status was confirmed through urine specific gravity measurement (≤ 1.020).

Ten minutes of seated rest preceded baseline measurements of intraocular pressure, nude body mass, body temperature and heart rate. Participants then commenced walking at 5 $km \cdot h^{-1}$ and 1% grade. Every 30 min participants had 10 min of seated rest, in which time intraocular pressure, nude body mass (after towelling dry), and body temperature were recorded. Heart rate was recorded in the final five minutes of each 30 min walking segment.

Intraocular pressure was measured by an ophthalmologist (Tiolat icare tonometer type TA01i, Icare, Helsinki, Finland) in triplicate for both right and left eyes. The average of all values was calculated as the participant’s intraocular pressure (Carbonaro et al. 2009). Body mass was measured with electronic scales accurate to the nearest 50 g (Tanita BWB-600, Wedderburn, Australia). Body temperature was measured in duplicate on the tympanic membrane via infrared thermometer (Thermoscan Pro 3000, Braun, Kronberg, Germany). Heart rate was monitored via telemetry (S610, Polar, Finland) and recorded manually.

Repeated measures analysis of variance was performed to assess the effects of time and condition on intraocular pressure, body mass loss, body temperature, and heart rate. Where the assumption of sphericity was violated, the Greenhouse-Geisser statistic was reported. Linear regression assessed the relationship between intraocular pressure (both absolute and change from baseline values) and body mass loss across all trials and time points. Adjusted coefficient of determination (r^2) and standard error of estimate were calculated. Statistical significance was set at $p < 0.05$.

Results

A significant interaction was observed for intraocular pressure with condition and time point (Greenhouse $F = 10.747$, $p = 0.009$) (table 1), indicating that over the duration of the trials, intraocular pressure declined to a greater extent in the hot compared to the temperate conditions. Statistically significant interactions were also observed for body mass loss (Greenhouse F = 50.083, $p < 0.001$), body temperature (F = 20.908, $p < 0.001$), and heart rate (F = 25.487, $p < 0.001$) (table 1).

A significant relationship was observed between body mass loss and intraocular pressure (F = 13.842, p = 0.001). However, body mass loss only accounted for a small proportion of the variance in intraocular pressure (adjusted $r^2 = 0.24$). The standard error of estimate was 0.99 mmHg. Alternatively, when using intraocular pressure change as the criterion variable (F = 43.235, $p < 0.001$), body mass loss accounted for a greater proportion of the variance (adjusted $r^2 = 0.51$) (figure 1). The standard error of estimate was 0.79 mmHg.

Discussion

The aim of this investigation was to determine if intraocular pressure during exercise differs in a temperate or hot climate with fluid restriction; promoting differing levels of dehydration. A significant interaction revealed intraocular pressure to decrease by a greater degree during the hot condition (table 1). In concert, body mass loss due to sweating was also significantly greater during the hot condition.

It has been suggested that dehydration could lower the rate of aqueous humor formation and reduce intraocular pressure (Harris et al. 1994). This hypothesis highlights the potential for a novel approach to the assessment of hydration status through the measurement of intraocular pressure. Although a significant relationship was observed in the present investigation, little of the variance (24%) in body mass loss accounted for the intraocular pressure observed. The variance in baseline values of intraocular pressure may partly explain this poor association. Baseline intraocular pressure was between 12 – 21 mmHg in this sample, a range similar to the general population (Oyster 1999). Within this large range, one individual's intraocular pressure when well hydrated may be below another individual's intraocular pressure when dehydrated by 2% body mass loss. To normalise intraocular pressure for this individual variation, the intraocular pressure change score was analysed. This approach improved the observed relationship (figure 1), whereby body mass loss accounted for 51% of the variance in intraocular pressure change. The moderate relationship observed suggests there is potential for intraocular pressure change to be a useful indicator of dehydration; however, further research is required to determine other factors influencing its variance, and to investigate greater levels of dehydration.

Significant interactions were also observed for body temperature and heart rate during the trials (table 1), and it could be suggested that these responses may have influenced intraocular pressure independently. Moura et al (2002) reported body temperature to increase during a period of exercise and decreased during an equivalent period of rest, however, the intraocular pressure response was the same during both conditions, showing that body temperature is not associated with intraocular pressure. The heart rate difference between trials in the present study is a result of the dehydration experienced (Sawka and Coyle 1999). Other researchers have observed no relationship between heart rate and intraocular pressure (Karabatakis et al. 2004). Whilst the current study cannot exclude the possibility that body temperature and heart rate influence intraocular pressure, the scientific literature does not support an association.

In conclusion, intraocular pressure was progressively reduced during a period of exercise causing dehydration, but remained relatively stable when hydration was maintained. The present study revealed a moderate relationship between dehydration (body mass loss) and intraocular pressure change. Further research should expand the range of dehydration and investigate other variables that may influence the intraocular pressure change.

Acknowledgements

The authors would like to acknowledge Amanda Rojek for her assistance with subject preparation and data collection. Andrew Hunt was funded by an Australian Postgraduate Award with an Institute of Health and Biomedical Innovation top up. Beatrix Feigl was funded by a Queensland University of Technology Vice Chancellor's post-doctoral fellowship.

Conflict of Interest

The authors declare they have no conflict of interest.

Figure captions:

Fig. 1 Linear regression of the intraocular pressure change and body mass loss during both conditions for the 30, 60, and 90 min time points (n = 42).

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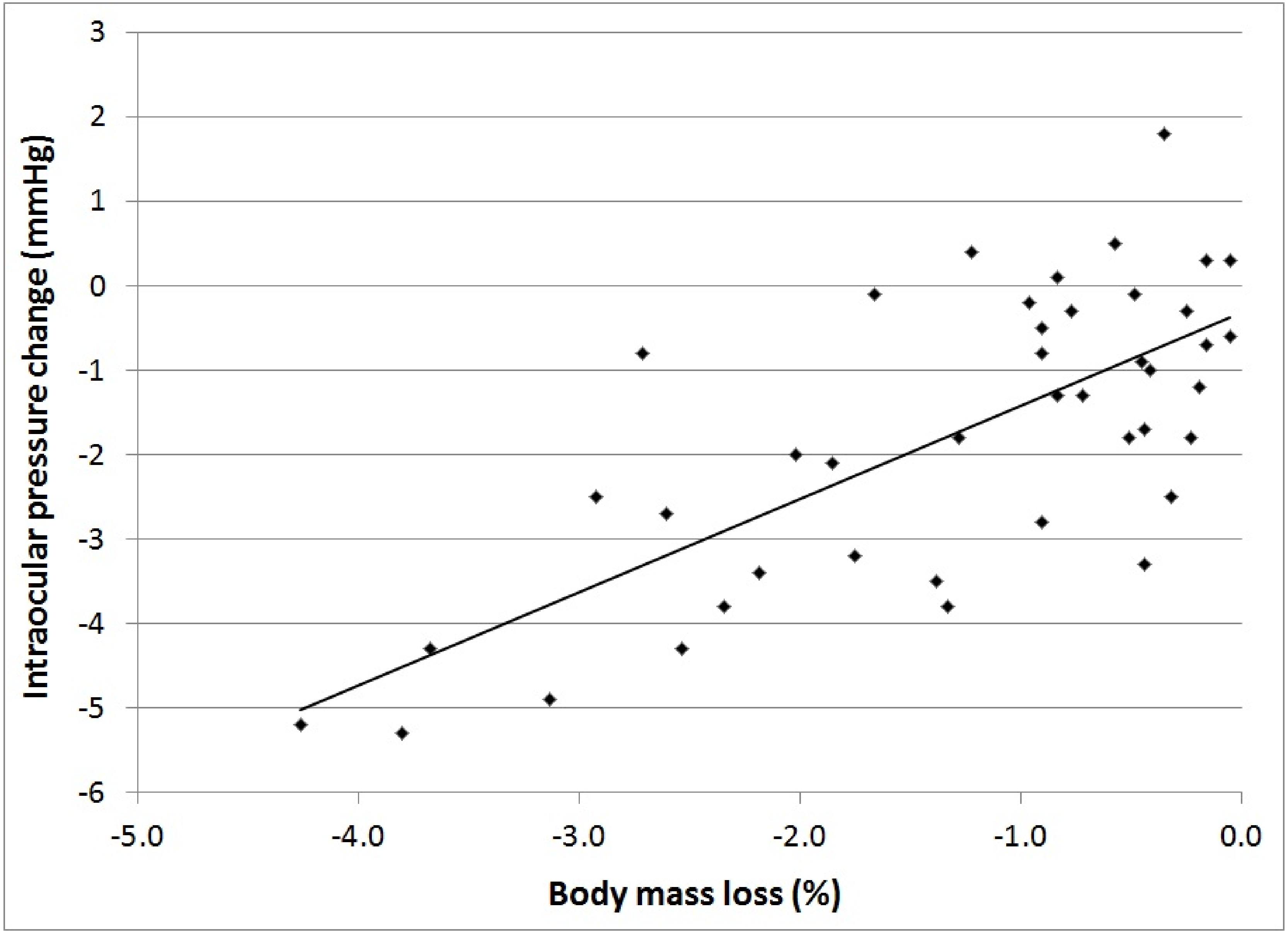
Table 1 Physiological changes observed during the hot and temperate conditions (mean ± standard deviation).

	Baseline		30 min		60 min		90 min	
Intraocular pressure (mmHg) *								
Hot	17.0	±2.9	15.6	±3.5	14.5	±3.7	13.6	±2.9
Temperate	16.8	±2.7	16.5	±2.6	15.8	±2.5	15.7	±1.8
Body mass loss (%) *								
Hot			-1.07	±0.35	-2.17	±0.55	-3.13	±0.74
Temperate			-0.15	±0.11	-0.47	±0.18	-0.78	±0.25
Body temperature (˚C) *								
Hot	36.5	±0.3	37.7	±0.3	38.06	±0.2	38.4	±0.3
Temperate	36.6	±0.7	36.8	±0.6	36.67	±0.7	37.0	±0.3
Heart rate (bpm) *								
Hot	57.6	±12.4	103.7	±12.2	111.7	±17.9	122.6	±21.8
Temperate	60.9	±10.2	89.3	±13.7	87.3	±14.0	90.2	±11.9

* Significant interaction effect ($p < 0.01$)


Intraocular pressure change (mmHg)
3
2
1
0
-1
-2
-3
-4
-5
-6
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
Body mass loss (%)