2.1 Abstract

Introduction: Water immersion exercise has been shown to acutely increase cerebral blood flow. Repeated acute increases in blood flow have been shown to improve long-term peripheral vascular health. This study examines the effect of varying water temperature during aqua cycling immersion exercise on cerebral blood flow.

Methods: Eight young healthy participants rested for 10 minutes, then cycled either on land or immersed to navel level in 32°C or 38°C water at 60rpm for three immediately sequential 10-minute stages of increasing resistance (5kg, 10kg and 15kg) before resting for five minutes. Middle (MCA_v) and posterior (PCA_v) cerebral artery velocity, mean arterial pressure (MAP), heart rate (HR), core temperature, end-tidal carbon dioxide ($P_{et}CO_2$), oxygen consumption (VO_2) and perceived exertion (RPE) were recorded throughout.

Results: MCA_v increased with exercise across all conditions and differed non-significantly between conditions. MCA_v was non-significantly higher during thermoneutral aqua cycling when compared to both hot aqua cycling and land cycling at every stage of the protocol, while MCA_v during hot aqua cycling was similar when compared to land at rest and after five minutes of low intensity exercise, but non-significantly lower through the remainder of the protocol.

Conclusion: Thermoneutral aqua cycling augments cerebral blood flow more than hot water aqua cycling at low to medium exercise intensity, while also being safer. Hyperthermic-related changes in centralisation of blood volume are likely the primary mechanism involved in varying the cerebral blood flow response between hot and thermoneutral water immersion exercise. As such, thermoneutral water should be utilised rather than hot water when attempting to induce acute increases in CBF via water immersion exercise.

2.2 Introduction

Cerebrovascular disease is an umbrella term referring to affliction of brain blood vessels, the most prominent being stroke and vascular dementia. It is Australia's second deadliest disease, after coronary heart disease, ending the lives of more than 10,000 people every year.

Economically, stroke alone was estimated to cost Australia $5 billion in 2012, with the total "burden of disease" totalling $49.3 billion. More than 400,000 stroke survivors experience lifelong residual effects, with 75% experiencing decreased employability and 30% suffering from post-stroke depression (1).

Extensive research has been undertaken to combat cerebrovascular diseases. A principal finding has been that repeated acute increases in cerebrovascular blood flow can significantly enhance cerebrovascular health (2). Increased blood flow induces mechanical loading, or "shear stress", on endothelial cells lining the walls of all blood vessels. Shear stress induces the production of nitric oxide (NO), a molecule that causes vasodilation by relaxing smooth muscle surrounding the vessels (3). Elevated endothelium-derived NO has been shown to have long-term anti-atherogenic effects, including inhibiting inflammatory cell activity, platelet aggregation and smooth muscle proliferation. Enhanced endothelial function as a consequence of repetitive increases in brain blood flow and shear stress also maintains the integrity of the blood brain barrier and decrease the risk of ischaemic and non-ischaemic cerebrovascular disease (2).

There are multiple mechanisms responsible for regulating cerebrovascular blood flow, including flow-metabolism (neurovascular) coupling, cerebral pressure autoregulation and metabolic control via agents such as arterial blood gases (4-6). Exercise is a potent stimulus to all of these mechanisms and exercise at moderate intensity (up to ~60% VO_{2max}) has been shown to increase CBF (7). Recently, it was reported that immersion of the body in 30°C water to the level of the heart also increase CBF at rest, due to hydrostatic pressure compressing superficial veins and increasing venous return, stroke volume, cardiac output and mean arterial pressure (8). Furthermore, combining exercise and water immersion appears to have an additive effect, increasing CBF more than either intervention alone (9, 10).

Optimising brain blood flow through immersion exercise has potential real-world benefits. Many individuals, especially those at higher risk of cerebrovascular diseases (e.g. the elderly and obese), struggle with land-based exercise due to frailty, debility and risk of falls. The buoyancy effect present during water immersion can alleviate the risks associated with exercise, with the potential dual benefit of also improving CBF (11). Identifying optimal conditions for immersion exercise should therefore be a research focus. However, no studies have directly investigated the relationship between water temperature and cerebral blood flow during water immersion exercise, leading to the aim of this study: *to investigate the effect water temperature has on cerebral blood flow during aqua cycling tasks.* We hypothesized that aqua cycling in thermoneutral water (32ºC) would induce higher cerebrovascular blood flows than exercise during hot water (38ºC) aqua cycling and a land-based control cycling condition.

2.3 Methods

2.3.1 Ethics

Subjects were provided a document outlining the experiment and all procedures involved. All provided written consent. The study conformed to the Declaration of Helsinki and was approved by the University of Western Australia's Human Research Ethics Committee (Ref: RA/4/1/5642).

2.3.2 Participants

Eight healthy young normotensive participants (23.3 ± 3.6 yr, 23.5 ± 3.1 kg/m^2, 7 ♂) were recruited (Table 2.1). All subjects were healthy with no injuries impeding cycling exercise, and no evidence of cerebrovascular, cardiovascular, metabolic or respiratory disorders. The sole female subject was tested during the early follicular phase of the menstrual cycle (days 1-7 of the cycle).

2.3.3 Experimental Design

In random order, each subject performed a land (control), thermoneutral water immersion (32°C) and hot water immersion (38°C) cycling condition, at the same time every day (± one hour) and with a minimum of 47 hours between conditions. All were fasted for a minimum of 8 hours, abstained from caffeine for a minimum of 12 hours and abstained from alcohol and vigorous physical exercise for a minimum of 24 hours prior to testing. Middle (MCA_v) and posterior (PCA_v) cerebral artery velocity, mean arterial pressure (MAP), heart rate (HR), core temperature, end-tidal carbon dioxide ($P_{et}CO_2$), oxygen consumption (VO_2) and perceived exertion (RPE) were recorded throughout each session.