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Original Research Article

The Effects of Hot Water Immersion on Fasting Blood Glucose and Lipids in a Prediabetic Population

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ABSTRACT

Purpose: This was a proof of concept study designed to examine the effects of two weeks of hot water immersion, compared to exercise, on fasted blood glucose and lipids in a prediabetic population. It was hypothesized that hot water immersion would improve fasted blood glucose and lipids compared to baseline; although, it was uncertain how those effects would compare to exercise. **Methods:** Three participants volunteered to undergo a two-week intervention of either exercise plus hot water immersion (EXHWI) or exercise (EX). The exercise intervention consisted of moderate aerobic activity and strength exercises, three times per week. Subjects in the EXHWI intervention underwent a similar amount of exercise, as well as four hot water immersion sessions per week. Measures of fasted blood glucose, lipids, height, weight, BMI, and waist circumference were measured before and after the two-week intervention. **Results:** In the EXHWI intervention, there was a 14% decrease in fasted blood glucose, 17.6% decrease in total cholesterol, 5.1% increase in HDL, 4.6% decrease in LDL, and a 41.3% decrease in triglycerides. There was little change in weight, BMI, or waist circumference. In the EX intervention, there was a 2.8% decrease in fasted blood glucose, 13.3% decrease in total cholesterol, 6.5% decrease in HDL, 5.8% increase in LDL, and a 30.6% decrease in triglycerides. There was little change in weight, BMI, or waist circumference. **Conclusion:** HWI provided increased benefits when combined with an exercise program on fasted blood glucose and lipids, compared to an exercise intervention alone. HWI may provide new therapeutic or preventative approaches against metabolic diseases such as prediabetes or dyslipidemia.

KEYWORDS: Dyslipidemia, Exercise Training, Heat Training, Hot Tub, Insulin Resistance.

Introduction

Type 2 diabetes mellitus (T2DM) has become an epidemic in the United States. In 2017, the Center for Disease Control and Prevention (CDC) published the *National Diabetes Statistics Report*, reporting that

9.4% of the United States population has diabetes, and a much larger 33.9% of the United States population has prediabetes. In addition, there are an estimated 1.5 million new cases of T2DM each year, and it is the seventh leading cause of death in the United States[1].

T2DM is a chronic metabolic disease characterized by hyperglycemia and insulin resistance[2]. In people with T2DM, insulin levels are normal or high, but liver, muscle, and adipose tissue becomes resistant to insulin[3]. This impairs the ability of these cells to take up and store glucose, which results in high levels of glucose circulating in the blood[2]. Insulin resistance is commonly associated with visceral adiposity, glucose intolerance, hypertension, and dyslipidemia, and has been shown to significantly increase the incidence and prevalence of cardiovascular disease[2]. One of the major complications of T2DM, diabetic dyslipidemia, is characterized by a decrease in HDL, an increase in small, dense LDL particles, and an increase in triglycerides[4]. This combination is commonly referred to as the 'atherogenic lipid triad' and is particularly linked to the development of atherosclerosis[5].

Exercise is a widely recommended intervention for improving insulin resistance as well as associated dyslipidemia, obesity, and hypertension[2,6]. Nonetheless, in populations that may benefit most from exercise, adherence is often poor, most likely due to medical conditions, disability, poor motivation, or a lack of convenience[6]. Despite the well documented health benefits of regular exercise, fewer than one in four adults meet the current recommendations for physical activity[7].

Recent research on the benefits of sauna use has shed light on the possibility of using heat exposure to induce many of the same benefits observed with moderate aerobic exercise[6,8]. In one of the earliest studies using heat exposure for people with T2DM, Hooper[9] examined the results of three weeks of hot water immersion in 38-41°C for 30 minutes a day, six days a week. It was found that subjects' plasma glucose level decreased by 12.6%, and their HbA1c decreased by 1%.

Faulkner et al.[6] compared a single intervention of 60 minutes in 40°C water to a single intervention of 60 minutes cycling at a matched metabolic heat production. This exposure was enough to significantly increase heat shock protein expression in both groups. Additionally, there was an increased reduction in peak glucose following heat exposure with no difference in 24-hour glucose area under the curve between the heat exposure and exercise intervention groups.

Although previous research on the potential benefit of using heat exposure to improve insulin resistance has been promising, there is still a lack of evidence for its use as an intervention for T2DM. Exercise is a well proven and evidence-based treatment for managing insulin resistance in those with T2DM[10]. However, to date, it is unknown how hot water immersion compares to exercise over a two-week intervention. Therefore, the purpose of this proof of concept study was to examine the effects of two weeks of exercise plus hot water immersion compared to exercise alone on blood glucose and lipids in a prediabetic population. It was hypothesized that hot water immersion would improve fasted blood glucose and lipids compared to baseline; although, it was uncertain how these effects would compare to exercise.

Methods

Participants

Three lightly active participants volunteered for this study. Subjects met inclusion criteria of having a fasted blood glucose above 100 mg/dL, not currently on medication for controlling diabetes, having at least one other diabetes risk factor, as defined by the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), exercising less than 150 minutes per week, and being able to exercise on a treadmill or stationary bike at least 20 minutes at 60% of their age predicted heart rate max. If subjects had any contraindications to exercise, as defined by the American College of Sports Medicine (ACSM), were pregnant, had severe complications of diabetes such as neuropathy, had any gastrointestinal disease, any recent surgeries, or had any implanted medical devices, they were excluded from this study. Subject characteristics are further described in Table 1.

Table 1. Subject Characteristics (Values are mean ± SD).

Characteristic	EXHWI (n=1)	EX (n=2)
Age (yrs)	64	82.5 ± 0.7
Height (cm)	170	166.5 ± 6.4
Weight (kg)	86	72.2 ± 17.5
BMI (kg/m^2)	29.7	25.8 ± 4.3
Waist Circumference (cm)	98	97.5 ± 19.1
Heart Rate (bpm)	84	73 ± 2.8
Systolic BP (mmHg)	126	124 ± 8.5
Diastolic BP (mmHg)	82	79 ± 1.4
Mean Arterial Pressure (mmHg)	97	94 ± 4.5
VO_2max (L/kg/min)	24.5	27.9 ± 3.9
Total cholesterol (mg/dL)	213	161 ± 33.9
HDL cholesterol (mg/dL)	78	60 ± 24.0
LDL cholesterol (mg/dL)	108	77 ± 1.4
Triglycerides (mg/dL)	133	121.5 ± 60.1
Fasted Blood Glucose (mg/dL)	114	105.5 ± 4.9
Oral Glucose Tolerance AUC	6261	11430.5 ± 6747.9

Data was collected in the High Altitude Performance Lab (HAPLab) at Western Colorado University in Gunnison, Colorado (2340m). Data was collected between the dates of February 10 and March 6, 2020.

For safety purposes, researchers did not allow subjects to undergo intervention if they had an abnormal heart rate or blood pressure measured before each intervention session, if subjects were intoxicated, or if there was a change in medical history or a severe progression in diabetic complications. All subjects signed an informed consent form prior to participation. This study was reviewed and approved by the Institutional Review Board at Western Colorado University [HRC2019-01-03-R73].

Experimental design

In a non-randomized experimental design, subjects were self-selected into either an exercise plus hot water immersion (EXHWI) or exercise (EX) intervention group for two weeks. Baseline and post-intervention measures were taken before and after the intervention.

Interested participants set up an appointment to come into the HAPLab. They were instructed further of the study design, commitments, risks, and benefits, and then given an opportunity to ask questions. Interested subjects then completed an informed consent, Physical Activity Readiness Questionnaire (PAR-Q), and Health History Questionnaire (HHQ). A series of baseline tests including resting heart rate, resting blood pressure, height, weight, BMI, waist circumference, and a submaximal VO_2 test were conducted to assess the subject's overall health and fitness. On a separate date, subjects were asked to come into the lab having fasted for at least 12 hours for a fasted lipid profile and 2-hour oral glucose tolerance test (OGTT). Those tests are described in detail further below.

After completing initial paperwork and baseline tests, subjects were self-selected into either the EX or EXHWI intervention group. Subjects in the exercise group underwent a supervised exercise program consisting of both moderate aerobic exercise and strength training Monday, Wednesday, and Friday mornings of each week. Subjects in the EXHWI intervention group underwent the same exercise program, with the addition of four hot water immersion sessions, Monday, Tuesday, Thursday, and Friday afternoons of each week. On Monday and Friday, the subject in the EXHWI intervention rested at least 6 hours between exercise and hot water immersion sessions. The two-week intervention occurred during February and March in Gunnison, Colorado and subjects had little or no heat adaptations during this time.

At the conclusion of the two-week intervention, subjects underwent post intervention testing, consisting of resting heart rate, resting blood pressure, height, weight, BMI, waist circumference, lipid profile, and fasted blood glucose. These tests were performed in the same order as baseline testing and collected approximately 24 hours after the last intervention session in order to allow adequate time for subjects to rehydrate. Subject's diet was not controlled during the intervention or testing. Experimental design is displayed in Figure 1.

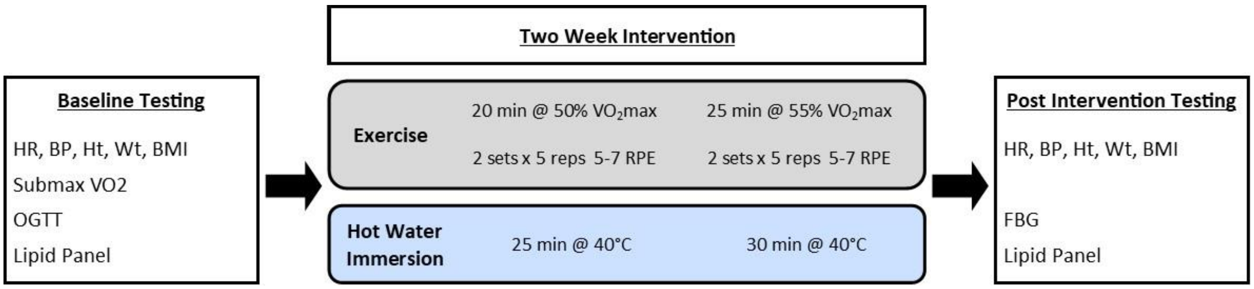

Figure 1. Experimental Design Flowchart.

Procedures

Resting Heart Rate

After being seated and resting for 5 minutes, the subject's resting heart rate was measured using a pulse oximeter (Concord Health Supply, Skokie, IL) placed on the subject's index finger of their right hand. This procedure took approximately 5 minutes, including resting time, and was done in the HAPLab.

Resting Blood Pressure

After taking resting heart rate, a blood pressure cuff (Mabis Healthcare Inc., Lake Forest, IL) was placed approximately one inch above the antecubital fossa of the subject's left arm and inflated to 220 mmHg. The pressure was released, and the researcher listened for the first and last Korotkoff sounds with a stethoscope (Mabis Healthcare Inc., Lake Forest, IL), indicating systolic and diastolic blood pressure, respectively. This process took place in the HAPLab and lasted approximately 2-3 minutes.

Height, Weight, BMI

The researcher had the subject remove their shoes and any bulky clothing and stand, back against the wall, on a scale (Tanita, Arlington Heights, IL) to be weighed (kg). A measuring stick built into the scale was used to measure the subject's height (cm). Subject's height and weight was measured in the HAPLab and took less than a minute. Body mass index (BMI) was later calculated using the formula BMI = weight (kg) / height (m)^2.

Waist Circumference

The researcher measured the subject's waist circumference (cm) using a flexible tape measure (DJO Global, Vista, CA) placed around the subject's torso at the narrowest point between the umbilicus and the xiphoid process. The subject was asked to inhale then exhale as the measurement was being taken to ensure they were not sucking in their stomach. Three measurements of waist circumference were taken and then averaged. This process took place in the HAPLab and lasted approximately 3 minutes.

Submaximal VO_2 test

At the same appointment as baseline testing, after all other data was collected, subjects underwent a submaximal VO_2 treadmill test using the Ebbeling treadmill test protocol in order to calculate their predicted VO_2max. The subject was first fitted with a heart rate monitor chest strap (Polar, Lake Success, NY) to monitor heart rate throughout the test. The subject warmed up by walking at a comfortable speed between 2.0 and 4.5 mph at a 0% incline with the goal of reaching 60% of the subject's age predicted heart rate max, using the HR_{max}=220 - age formula. Once the subject reached their target heart rate, the speed was kept constant and the incline was increased to 5% and the subject continued at this stage for 4 minutes. The researcher recorded heart rate at the end of every minute. The last two recorded heart rates were averaged. If the heart rate varied by more than five beats per minute between the last 2 minutes, the test was extended by an additional minute. At the end of the test, the subject was allowed to cool down as needed. VO_2max was predicted using the formula VO_2max=15.1 + (21.8 x mph) – (0.327 x HR) – (0.263 x mph x age) + (0.00504 x HR x age) + (5.98 x sex*) (*Females=0, males=1)[11].

Lipid Panel

Subjects were asked to come into the HAPLab having fasted for at least 8 hours, and refrain from exercise, caffeine, or smoking during this time. The subject was asked to wash their hands with soap and warm water and then dried. The subject's preferred finger was then wiped with an alcohol wipe and allowed to dry. The tip of the subject's finger was punctured using a lancet (Medipurpose, Brussels, Belgium), and a finger stick sample was collected into a heparin-coated 40 µl capillary tube (Abbott, Abbott Park, IL). Samples were dispensed immediately onto commercially available test cassettes (Abbot, Abbot Park, IL) for analysis in an LDX Cholestech analyzer (Abbott, Abbott Park, IL). The Cholestech provided measures of fasted blood glucose, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, and triglycerides. A daily optics check was performed on the LDX Cholestech analyzer used for the study. This process took 10 minutes and took place in the HAPLab. Subjects were not allowed to eat any food until results were recorded.

Oral Glucose Tolerance Test

At the same testing date as the lipid panel, subjects also underwent a 2-hour Oral Glucose Tolerance Test. Following the lipid panel, using the same finger, the researcher collected a small drop of the subject's blood on a glucometer testing strip (Ascensia Diabetes Care, Parsippany, NJ) and the subject's fasted blood glucose was analyzed using a glucometer (Contour Next One, Ascensia Diabetes Care, Parsippany, NJ).

Subjects were instructed to drink an 8 oz glucose solution that contained 75 grams of glucose (Azer Scientific Inc., Morgantown, PA) within 5 minutes. Immediately after the subject consumed this drink blood was drawn as described above and analyzed for blood glucose. The subject's blood glucose was then measured every 5 minutes for the first 30 minutes, and then every 15 minutes for the remaining 90 minutes. This procedure occurred in the HAPLab and lasted approximately 120 minutes.

Core Temperature

To ensure that core temperature did not exceed 40°C, core temperature was measured during the subject's first hot water immersion session. It was assumed that if the subject had a safe core temperature response during the first intervention, this response would stay constant or decrease during the rest of the intervention. Core temperature was measured with a small, jellybean sized temperature sensor pill (HQ Inc., Palmetto, FL), which the subject ingested two hours before the hot water immersion session, and a core temperature analyzer (HQ Inc., Palmetto, FL). The analyzer was held close to the subject's abdomen for 20 seconds in order to get a reading.

Exercise Intervention

Subjects in the exercise intervention group underwent a supervised exercise program consisting of both moderate aerobic exercise and strength training, three days a week. Exercise sessions were done Monday, Wednesday, and Friday mornings of each week. Aerobic exercise consisted of 20 minutes on a stationary recumbent bike (Life Fitness, Rosemont, IL). Aerobic exercise intensity was based on an established percentage of maximal heart rate. Strength training consisted of four exercises: chair squats, step-ups, bicep curl, and shoulder press. Exercise was progressed in duration and intensity during the two-week intervention. Exercise sessions were monitored by at least two researchers and took place in the Western Colorado University fieldhouse gym. Water was provided as desired during the exercise session. Resting heart rate and blood pressure were measured before and after each session. Exercise sessions were held at the same time of day for each subject to avoid error due to normal fluctuations in the subject's blood glucose levels. Subjects were asked not to eat anything within one hour prior to intervention as well as to keep normal habits for eight hours before intervention.

Exercise plus Hot Water Immersion Intervention

The exercise plus hot water immersion intervention consisted of the same exercise program plus an additional hot water immersion program. Hot water immersion sessions were held Monday, Tuesday, Thursday, and Friday afternoons of each week. The hot water immersion intervention consisted sitting, immersed to the neck, in a 40°C hot tub (Coleman SaluSpa, Bestway, Phoenix, AZ). Hot tub sessions were monitored by at least two researchers in order to ensure subject's safety. Researchers were trained to recognize and watch for signs of heat stress. Water was provided as desired during each session. Resting heart rate and blood pressure were measured before and after each session. All hot water immersion sessions took place in the HAPLab and were held at the same time of day for each subject to avoid error due to normal fluctuations in the subject's blood glucose levels. Subjects were asked not to eat anything within one hour prior to intervention as well as to keep normal habits for eight hours before intervention.

Statistical Analyses

Because this was a proof of concept study with an n of 3, data were analyzed descriptively. Mean, standard deviation and percent change were calculated for all pre- and post-intervention variables in order to measure improvements in both the exercise plus hot water immersion (EXHWI) and exercise (EX) intervention groups. Metabolic z-score (MetS z-score) was calculated for each subject pre- and post-intervention. Additionally, the dose-response relationship of EXHWI and the percent change due to HWI was predicted from the difference in percent change between the two intervention groups.

Results

Four subjects underwent baseline testing. Of these subjects, three completed a full two weeks of intervention, and one subject had to drop out shortly after baseline testing for reasons unrelated to the study. Two subjects were self-assigned to the exercise intervention group (EX). One subject was self-assigned to the exercise plus hot water immersion intervention group (EXHWI). All three subjects underwent post-intervention testing at the end of week two of the intervention. Subjects' oral glucose tolerance and VO_2max were measured before intervention, though these measures were not taken post-intervention, and therefore, are not included in the results. The two week-intervention occurred between February 24 and March 5, 2020. Baseline testing occurred between February 10 and February 19, 2020, and post-intervention testing occurred on March 5 and 6, 2020.

Subject Adherence and Enjoyment

Overall, there was good subject adherence over the two-week period. The subject in the EXHWI intervention completed all six exercise sessions, as well as seven of the eight hot water immersion sessions, missing one due to personal reasons. One HWI session had to be rescheduled for the next morning due to unsafe chemical levels in the hot tub. The subjects in the EX intervention completed five of the six exercise sessions, missing one due to personal reasons. Both interventions were well tolerated. No injury or illness due to the intervention was reported during the study period. The subject in the EXHWI intervention group had their core temperature measured during the first session, and it did not exceed 40°C. All subjects expressed enjoyment through their intervention sessions.

Main Outcomes

Main variables of interest included changes in fasted blood glucose, HDL, LDL, total cholesterol, and triglycerides. Pre- and post-intervention measures of these variables for both EXHWI and EX interventions are shown in Figures 2 and 3. For other variables, refer to Table 2.

Table 2. Pre- and Post- Intervention Measures in EXHWI and EX Interventions (Data are means ± SD).

Measure	EXHWI (n=1)			EX (n=2)		
	Pre	*Post*	*% Change*	*Pre*	*Post*	*% Change*
Age (yrs)	64	64	0%	82.5 ± 0.7	82.5 ± 0.7	0%
Height (cm)	170	170	0%	166.5 ± 6.4	165.3 ± 8.1	- 0.8 ± 1.1%
Weight (kg)	86	88.2	2.5%	72.2 ± 17.5	71.5 ± 17.2	- 0.9 ± 0.3%
BMI (mg/m^2)	29.7	30.5	2.7%	25.8 ± 4.3	25.9 ± 3.7	1.6 ± 0.8%
WC (cm)	98	106	8.2%	97.5 ± 19.1	95 ± 14.8	-2.8 ± 3.1%
Heart Rate (bpm)	84	82	-2.4%	73 ± 2.8	78.5 ± 2.1	7.7 ± 7.1%
SBP (mmHg)	126	120	-4.8%	124 ± 8.5	111 ± 1.4	-10.3 ± 4.9%
DBP (mmHg)	82	68	-17.1%	79 ± 1.4	61 ± 4.2	-22.8 ± 3.9%
MAP (mmHg)	97	85	-12.4%	94 ± 4.5	77.5 ± 3.5	-17.5 ± 0%
TC (mg/dL)	213	200	-6.1%	161 ± 33.9	152 ± 25.5	--5.6 ± 11.8%
HDL (mg/dL)	78	82	5.1%	60 ± 24.0	57 ± 26.9	-5.0 ± 7.3%
LDL (mg/dL)	108	103	-4.6%	77 ± 1.4	78.5 ± 7.8	1.9 ± 2.6%
TRI (mg/dL)	133	78	-41.4%	121.5 ± 60.1	82 ± 32.5	-32.5 ± 7.5%
FBG (mg/dL)	114	98	-14.0%	105.5 ± 4.9	105.5 ± 9.2	0.0 ± 0.1%
MetS zScore	-0.89	-3.41		-2.37 ± 4.16	-4.57 ± 4.17	

Note: Abbreviations: body mass index (BMI), waist circumference (WC), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides (TRI), fasted blood glucose (FBG), metabolic z-score (MetS zScore).

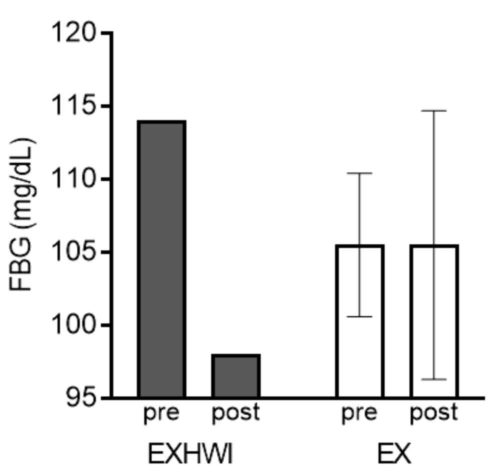

Figure 2. Pre and post-intervention fasted blood glucose (FBG) in exercise plus hot water immersion (EXHWI) and exercise (EX) interventions. Data are presented as means ± SD.

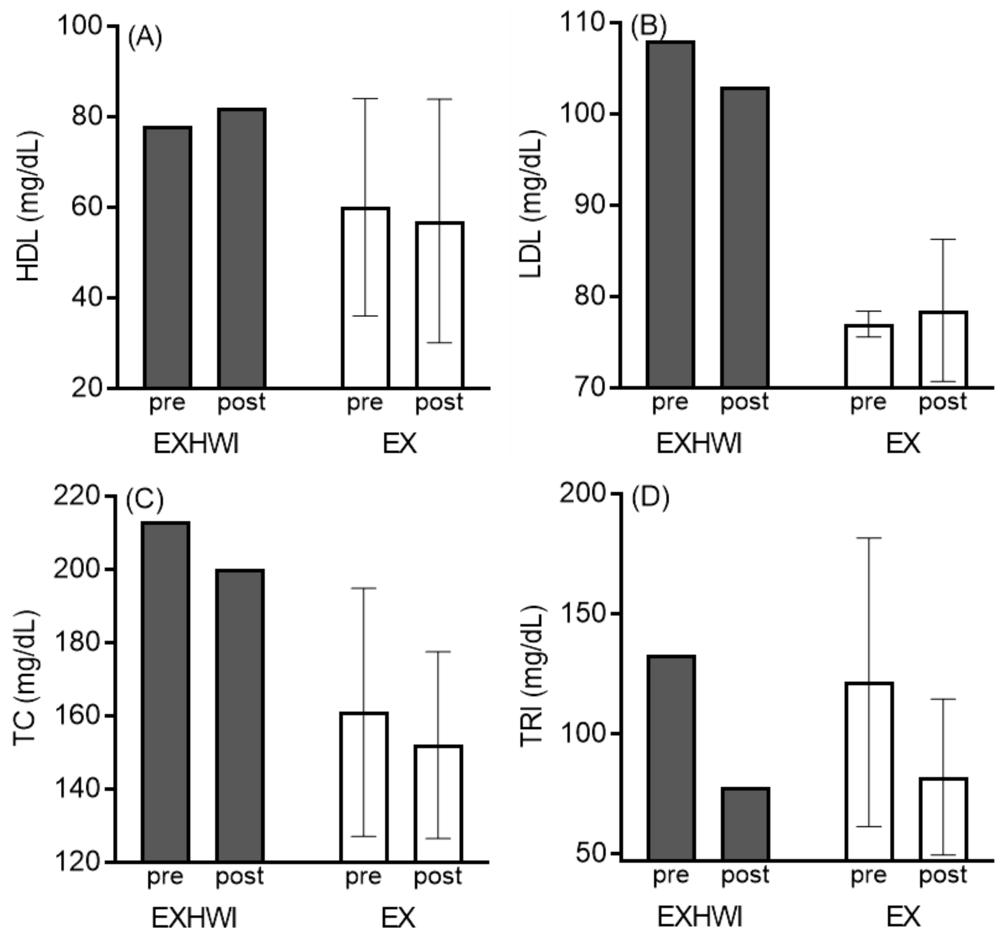

Figure 3. Pre and post-intervention lipid profile in exercise plus hot water immersion (EXHWI) and exercise (EX) interventions; including: (A) high density lipoproteins (HDL), (B) low density lipoproteins (LDL), (C) total cholesterol, and (D) triglycerides. Data are presented as means ± SD.

Discussion

Fasted Blood Glucose

Chronic hyperglycemia, resulting from uncontrolled glucose regulation, has been established as the cause of both prediabetes and T2DM, as well as their associated complications[12]. There was an observed 14% decrease in fasted blood glucose (FBG) in the EXHWI intervention. The subject in this group went from being classified as prediabetic to being within the normal range for fasted blood glucose. The mean FBG stayed constant in the EX intervention group. This decrease in FBG with the addition of HWI is consistent with findings from previous research[9,13,14,15]. Previous research has also shown that FBG decreases with exercise training[16,17], ranging anywhere from a little over 1% to as much as 4%[16,17]. In the current study, the marked 14% decrease in FBG may have been due to the addition of HWI to the exercise program. In this way, the addition of HWI may provide added benefits in lowering blood glucose and slowing or preventing the progression of prediabetes or T2DM.

Lipids

Dyslipidemia, characterized by a total cholesterol greater than 200 mg/dL, HDL lower than 40 mg/dL, LDL greater than 130 mg/dL, or triglycerides greater than 200 mg/dL, is commonly seen in individuals with prediabetes, and contributes to the risk of developing cardiovascular disease[18].

There was a 6.1% decrease in total cholesterol (TC) in the EXHWI subject, decreasing from borderline high TC levels to almost desirable. Other previous studies have also shown that regular heat exposure may lower TC levels[19,20,21]. Pilch et al.[22] found an 8.7% decrease in TC following seven, 30-minute sauna sessions, every other day, in healthy individuals. The lesser decrease in TC observed in the present study may be due to preexisting metabolic dysfunction. Additionally, TC decreased by 5.6% in the EX intervention group. Other studies that used 90 and 135 minutes of aerobic exercise per week found a 5.6% and 12% decrease, respectively[16,23]. The current study found a 0.5% greater decrease in TC with the addition of HWI, suggesting an added benefit of HWI when combined with exercise.

Previous research has shown that both HWI and exercise increased levels of HDL[19,23,24]. Gryka et al.[24] found a 7% increase in HDL following an intervention of ten, 45-minute sauna sessions, every other day, in healthy subjects. Indeed, a meta-analysis from Durstine et al.[23] reported that repeated moderate intensity aerobic exercise may increase HDL as much as 51%. An increase in HDL is desirable, as it indicates improved metabolic health and a decreased risk of developing CVD or T2DM related complications[18]. Interestingly, the present study found an increase in HDL of 5.1% in the EXHWI intervention, and a decrease of 5% in the EX intervention. The increase in HDL seen with the EXHWI group is expected, as other studies have found a similar increase[19,24]. The decrease in HDL seen in the EX intervention is surprising, but it may have been due to inadequate exercise intensity, or possibly the effect of insulin on HDL[25], though this is yet to be determined.

Following a similar pattern, it was found that LDL decreased by 4.6% in the EXHWI intervention group and increased by 1.9% in the EX intervention group. This finding in the EX group was unexpected, as previous research reports that exercise results in either a decreased or unchanged level of LDL[23]. Studies that have found decreases in LDL report a 4% to 20% decrease with moderate intensity aerobic exercise[23]. Previous studies have also shown that heat exposure decreases LDL[22,24]. For instance, in an intervention of ten sauna sessions, every other day, Gryka et al.[24] found a 3.7% reduction in LDL cholesterol. Further, Pilch et al.[22] found an 11% reduction in fasted LDL concentration after two weeks of repeated 30-minute sauna sessions, every other day. Our results add to the current literature that two weeks of repeated HWI sessions decreased LDL by 4.6%, and that the addition of exercise provided no benefit to this decrease.

Triglycerides have been shown to be significantly higher in prediabetic individuals, and increase the risk of atherosclerosis, stroke, and CVD[18]. We found that triglycerides decreased by 41.4% in the EXHWI intervention and decreased by 32.5% in the EX intervention. The subject in the EXHWI intervention decreased from having borderline high triglycerides to an optimal level. This decrease in triglycerides with exercise is expected, as another study found that triglycerides decreased by as much as 87 mg/dL with 90 minutes of exercise per week, at 75% VO_2max, for 12 weeks[23]. We found that a smaller, 30.6%, decrease can be observed in as little as two weeks. There have been mixed findings relating heat exposure to level of triglycerides. Gryka et al.[24] found a small, 18% decline in triglyceride levels after three weeks of repeated 45-minute sauna sessions. Contrary, Pilch et al.[22] found a 12.1% increase in triglycerides following seven 30-minute sauna sessions every other day. Comparing EXHWI to EX, there is approximately an 11% difference that may be due to HWI intervention alone. This would be in line with the findings from Gryka et al.[24], providing additional evidence suggesting that heat exposure decreases triglycerides.

Metabolic Syndrome Z-Score

Metabolic syndrome z-score (MetS z-score) was calculated for each subject as a predictive measure of cardiometabolic health as well as to assess responsiveness to intervention. It was observed that the MetS z-score decreased by 2.52 in the EXHWI intervention, and by 2.2 in the EX intervention. The MetS z-score has been shown to have strong associations with insulin resistance and T2DM, and it provides a predictive model of assessing risk and prevalence[26]. Using the MetS z-score provides a more robust measure of cardiometabolic health, as it accounts for several different factors (blood pressure, triglycerides, fasted blood glucose, HDL, and waist circumference), rather than using these measures alone. Ramos et al.[27] found that reducing the MetS z-score by 0.15 confers approximately a 10% improvement in one of the MetS components, leading to a reduction in CVD risk. Use of the MetS z-score also provides an indication of responsiveness to intervention. It has been previously found that a reduction in the z-score greater than 0.6 indicates an improvement in cardiometabolic health above what we could expect due to biological variability[28]. Based on our observed MetS z-scores, we can confidently state that both EXHWI and EX interventions were effective and provided benefits in cardiometabolic health.

Limitations

This was a proof of concept study, investigating potential cardiometabolic benefits of HWI, and there were a few key limitations. Due to a small sample size, data had to be compared descriptively, and inferential statistics were unable to be conducted. Because of this, it is almost impossible to confidently state whether observed benefits in the EXHWI over the EX intervention were actually due to the addition of HWI. Subjects were allowed to continue normal daily activity throughout the study.

Researchers did not attempt to control for dietary intake or levels of physical activity, whether structured exercise or activities of daily living. Due to the outbreak of COVID-19, researchers were unable to measure subject's post-intervention oral glucose tolerance or VO_2max.

Future Research

The present study found that hot water immersion provides additional benefits in lowering fasted blood glucose and improving the lipid profile. This is one of the few studies attempting to compare HWI to exercise in relation to metabolic benefits. Further research should be done to explore the affect and identify a dose-response relationship of HWI, and how this equates to the benefits of moderate aerobic exercise. We used an intervention of two weeks, and it is unknown how decreases in lipids and blood glucose will respond to incorporating HWI as a lifestyle factor for a longer period of time. It is likely that levels will eventually plateau, but this trend is currently unknown.

Applications

Research suggests that a combination of HWI, in addition to exercise, is associated with greater cardiometabolic health and a substantial reduction in the risk of cardiovascular disease compared to each modality alone[8]. HWI may be desirable in that it provides a physiological stress, much like exercise, without stressing structural anatomy such as muscles or joints. In this way, it may be an ideal lifestyle intervention for enhancing health and wellness, particularly in populations that have difficulty exercising, or who may be unable to increase their current level of physical exercise[8]. There is previous anecdotal evidence that people with cardiovascular disease are discouraged from having sauna baths because the hot and humid environment imposes a burden on the cardiovascular system[8]. However, the current literature suggests that sauna bathing is safe for patients with stable CVD[8]. Overall, HWI is safe, enjoyable, and well tolerated, and can be linked to a remarkable array of health benefits. It may provide an additional therapeutic lifestyle intervention in addition to exercise, or for those who may be unable to exercise.

Conclusion

The results of the present study suggest that hot water immersion may be beneficial for lowering fasted blood glucose and improving overall cardiometabolic health in a prediabetic population. Either as its own intervention, or combined with exercise, hot water immersion has been shown to improve blood glucose, lipids, heart rate, blood pressure, and body composition. These improvements can be beneficial for improving health, and moving an individual from unhealthy categories, to healthy. These findings suggest that hot water immersion may provide new therapeutic or preventative approaches against metabolic diseases such as prediabetes and dyslipidemia.

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