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Different Immersion Temperatures' Impact Upon Blood Pressure of Individuals With Varied Sex and Age

**Kasee Hildenbrand, Celestina Barbosa-Leiker,
and Daniel Melchior**

Warm water immersion is known to have an effect on human cardiovascular function. This study examines how age (young = 18–30 years and older = 31–65 years) and sex influence changes in blood pressure due to submersion in different water temperatures. Fifty-eight individuals sat immersed to the neck in three different water temperature tanks. Blood pressure measurements (systolic/diastolic blood pressure [SBP/DBP], pulse pressure [PP] and heart rate [HR]) were collected every 6 minutes throughout the duration of the test. We observed significant between-group, within-group, and interaction effects for SBP, DBP, and HR. For PP, significant between-group and within-in group effects were found. Additional post hoc analyses found that from baseline to cool immersion, older females (OF) had less change in SBP values compared to younger males (YM) and younger females (YF) and less change in DBP values compared to YM. From warm immersion to recovery, older males (OM) had less change in heart rate compared to YM, and in both the warm and cool immersions, YF lower pulse pressure than YM. Understanding changes to BP during resting water immersion across different ages and both sexes could have clinical applications relevant to both physicians and those responsible for rehabilitation of cardiovascularly-compromised patients.

Seated sternal notch level water submersion (such as in a hot tub) is a common recreational and sometimes therapeutic activity enjoyed by people worldwide. Very little research has observed how this activity affects physiological indicators of blood pressure and heart rate during and after water immersion or the mechanisms involved. The prevailing motivation for exploring the physiological effects and associated mechanisms of water immersion is driven largely by the need to understand the limits of human survival in extreme conditions. A subset of previous studies have focused on select segments of the human population exhibiting various forms of heart disease while others focused on military or space flight applications.

Water immersion profoundly affects human function with health-related biologic consequences, specifically immersion related to temperature and hydrostatic pressure. Thermo-neutral water immersion (35°– 36°C) to the sternal notch redistributes approximately 700 ml of blood from the peripheral vascular system

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to the thoracic cavity, resulting in increased thoracic blood volume, central venous pressure, and cardiac output (Arborelius, Balldin, Lilja, & Lundgren, 1972; Begin et al., 1976; Christie et al., 1990; Park, Choi, & Park, 1999). This shift in blood could be beneficial since it allows the heart to work less. At the same time, warm immersion decreases peripheral resistance to blood flow, reducing the amount of work the heart must do to move the increased volume of blood, so the effort required to circulate blood decreases while cardiac efficiency increases (Arborelius et al., 1972; Gabrielsen, Johansen, & Norsk, 1993b).

In addition, the hydrostatic pressure redistribution associated with water immersion affects blood pressure (BP) and increases the preload of the heart. This is particularly important for older individuals whose adaptability to environmental changes decreases with age (Asahina et al., 2010; Kenney & Munce, 2003; Park et al., 1999; Sramek, Simeckova, & Jansky, 2000). As central blood volume increases, the venous return is increased, which puts the heart ventricles on greater stretch thereby increasing the efficiency of the heart. Immersion may also facilitate an increase in cardiac filling volume (Begin, et al., 1976; Bonde-Petersen, Schultz-Pedersen, & Dragsted, 1992; Christie et al., 1990; Gabrielsen, Johansen, & Norsk, 1993a; Sramek et al., 2000). Due to this increase in stroke volume, immersion may be one useful way of beginning cardiac rehabilitation (Cider, Svealv, Tang, Schaufelberger, & Andersson, 2006).

During head-out thermo-neutral water immersion, the ambient hydrostatic pressure reduces vascular capacitance, which leads to the relocation of peripheral blood into more compliant thoracic musculature. Venous return, central venous pressure, and the heart dimensions are all increased leading to the stimulation of baroreceptors (Ueno et al., 2005). In some cases, previous research reports in thermo-neutral water immersion BP is unchanged or decreased, and HR is reported to decrease (Bonde-Petersen et al., 1992; Gabrielsen et al., 2000; Miwa, Sugiyama, Iwase et al., 1997; Miwa, Sugiyama, Mano, Iwase, & Matsukawa, 1997; Nishimura & Shoonodera, 2001). In other research using the same immersion at 32° C, BP rises during immersion, while HR decreased (Asahina et al., 2010; Park et al., 1999). There is little consensus on why the results differed, but most likely they stemmed from methodological differences.

No research to date has examined how adult age and sex differences affect the physiological changes associated with water immersion. Most previous studies have focused on a small select group of 5 to 10 individuals with all members sharing similar sex, age, or physical attributes. Therefore, the purpose of this study was to observe whether heart rate and blood pressure changes induced by seated sternal notch level immersion in water at different temperatures varied according to adult participants' age and sex.

Method

Participants

This study protocol was reviewed and approved by the university's Institutional Review Board. Participants were recruited through a university list serve. Require-

ments and criteria for participation was a 3-hour time commitment, no fear of water immersion to the sternal notch, and absence of any medications that are known to alter blood pressure or heart rate.

A total of 58 individuals participated in this study: 21 males younger than 30 years (younger males, YM), 21 females younger than 30 years (younger females YF), 6 males older than 30 years (older males, OM), and 10 females older than 30 years (older females, OF). We grouped participants into younger (18–30 years) and older (31–65 years) groups due to changes found in blood pressure based on research from the Framingham Heart Study that reported a linear rise in resting blood pressure after age 30 (Franklin et al., 1997). There were fewer older participants due to time requirement and difficulty in recruiting older individuals on the college campus. Resting measurements of heart rate and blood pressure were taken once at each data collection point using a standard automated plethysmometer (OMRON HEM-755, Omron Healthcare, Inc, Bannockburn IL). Demographics and physiological measures are presented in Table 1.

Protocol

The water immersion temperatures were chosen based on the requirements of a larger study (Hildenbrand, Becker, Whitcomb, & Sanders, 2010). The cool immersion tank was kept at 31° C, the thermoneutral tank was at 36° C, and the warm tank was at 39° C. The cool tank temperature was selected after experimentally discovering a water temperature that individuals could easily tolerate for 24 minutes without shivering. This temperature also represents the lower range for therapeutic pools (31–33° C). The neutral tank was at 36° C, which is above some previous definitions of thermo-neutral temperatures (i.e., 34–35° C) but was comparable to the resting body temperature of 36.6° C. The warm tank was at 39° C, which is just under the maximum regulation temperature of 40° C recommended by the U.S. Consumer for Product Safety Commission for therapeutic hot plunges and hot tubs. This slight reduction in temperature was necessary to allow individuals to stay immersed comfortably for the 24 minutes during which data were collected.

Participants rested in a seated position next to the immersion tank for six minutes before initial blood pressure and heart rate measurements were taken. Subjects were then immersed in the cool (31°C) tank (C) for 24 minutes. BP and HR were measured four times while in the cool tank and then averaged for statistical comparison. Afterward, subjects exited the cool water and rested poolside for 12 minutes. Participants were then immersed in neutral (36° C) water (N) for 24 minutes, followed by recovery for 12 minutes. Finally, participants were immersed in the warm (39° C) tub (H) for 24 minutes before sitting at the side of the immersion tank for a final 12 minutes. BP and HR were taken at end of the third recovery period (R3). Pulse pressure (PP) was also calculated and examined (SBP-DBP = PP) to allow for comparisons with previous studies using medication therapies. The order of presentation of water temperatures was not randomized, as previous examinations from our lab showed that the order of immersion temperatures did not have an effect on data measurements (unpublished data) and patient comfort was considered for ending in the warm water.

Table 1 Demographics and Physiologic Measures

Group	Subjects	Age		Height		Weight		BMI	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Young Male (YM)	21	21.52	2.32	69.31	4.88	177.36	30.35	26.03	4.23
Young Female (YF)	21	20.62	1.80	66.11	1.34	154.47	27.79	24.8	4.15
Older Male (OM)	6	50.67	8.33	70.50	3.21	198.52	25.21	28.28	4.89
Older Female (OF)	10	49.00	10.60	63.94	3.36	160.80	52.48	27.62	8.03

Statistical Analysis

In order to examine differences across the age/sex groups over the immersion temperatures, a 4 (between groups: older females vs. older males vs. younger females vs. younger males) \times 5 (within groups: baseline vs. cool vs. neutral vs. warm vs. recovery) mixed factorial ANOVA was used. Significant interactions were analyzed post hoc using one-way between-groups ANOVAs of change scores across changes in immersion temperatures, followed by Tukey LSD post hoc tests. Significant between- and within-groups effects without a significant interaction were analyzed using one-way between- or within-groups ANOVAs, followed by Tukey LSD post hoc tests. Bonferonni corrections for levels of significance (.05/6) were used for all post hoc tests, resulting in a post hoc p -value of .008 for significance.

Results

Systolic blood pressure. The 4 (between groups: age/gender groups) \times 5 (within groups: immersion temperatures) mixed factorial ANOVA resulted in a significant between groups effect, $F(3, 54) = 8.65, p < .001$; a significant within-groups ANOVA, $F(4, 216) = 24.11, p < .001$; and a significant interaction, $F(12, 216) = 3.80, p < .001$. Estimated marginal means for all variables are presented in Table 2 and Figure 1A. Post hoc tests were performed on the changes from baseline to cool immersion and from neutral immersion to warm immersion. From baseline to cool immersion, there was a significant between-groups effect for the change scores, $F(3, 54) = 6.45, p = .001$, where older females ($M = .67, SD = 7.71$) significantly differed from younger females ($M = -9.06, SD = 7.93$), $p < .001$ and from younger males ($M = -11.556, SD = 8.75$), $p = .003$; older females had increased systolic blood pressure values from baseline to cool immersion compared to the younger participants, who had decreased values.

Diastolic blood pressure. The 4 (between groups: age/gender groups) \times 5 (within groups: immersion temperatures) mixed factorial ANOVA resulted in a significant between groups effect, $F(3, 54) = 13.60, p < .001$; a significant within-groups ANOVA, $F(4, 216) = 71.65, p < .001$; and a significant interaction, $F(12, 216) = 2.28, p < .01$. Estimated marginal means for all variables are presented in Table 2 and Figure 1 B. Post hoc tests were performed on the changes from baseline to cool immersion, and from neutral immersion to warm immersion. From baseline to cool immersion, there was a significant between-groups effect for the change scores, $F(3, 54) = 3.98, p = .01$, where older females ($M = -3.00, SD = 8.36$) significantly differed from younger males ($M = -14.05, SD = 7.27$), $p = .001$; older females had less decrease in diastolic blood pressure values from baseline to cool immersion compared to younger males .

Heart rate. The 4 (between groups: age/gender groups) \times 5 (within groups: immersion temperatures) mixed factorial ANOVA resulted in a significant between groups effect, $F(3, 54) = 5.26, p < .01$; a significant within-groups ANOVA, $F(4, 216) = 66.78, p < .001$; and a significant interaction, $F(12, 216) = 2.26, p < .01$. Estimated marginal means for all variables are presented in Table 2 and Figure 1C. Post hoc tests were performed on the changes from neutral immersion to warm

Table 2 Mean Values for Age and Gender in Various Water Temperature Immersion States

Water Immersion	B - baseline		C - cool		N - neutral		H - hot		R3 - rest 3	
	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)	Mean (± SE)
Pulse Pressure										
YF	37.00 (± 1.86)	38.32 (± 1.52)	36.42 (± 1.68)	44.56 (± 1.84)	36.00 (± 1.86)					
YM	43.86 (± 1.86)	46.35 (± 1.52)	47.16 (± 1.69)	52.91 (± 1.84)	49.33 (± 1.87)					
OF	40.20 (± 2.69)	43.88 (± 2.21)	40.08 (± 2.44)	44.53 (± 2.67)	38.85 (± 2.70)					
OM	39.33 (± 3.47)	46.75 (± 2.85)	44.63 (± 3.15)	50.38 (± 3.45)	39.83 (± 3.49)					
Systolic Blood Pressure										
YF	110.71 (± 2.22)	101.66 (± 2.51)	96.929 (± 2.24)	99.49 (± 2.34)	104.36 (± 2.43)					
YM	118.43 (± 2.22)	106.87 (± 2.51)	103.80 (± 2.24)	107.51 (± 2.34)	117.74 (± 2.43)					
OF	120.00 (± 3.22)	120.68 (± 3.64)	109.98 (± 3.25)	107.33 (± 3.39)	111.70 (± 3.52)					
OM	125.33 (± 4.16)	123.42 (± 4.70)	117.67 (± 4.19)	120.92 (± 4.38)	124.08 (± 4.54)					
Diastolic Blood Pressure										
YF	73.71 (± 1.93)	63.33 (± 1.86)	60.51 (± 1.44)	54.93 (± 1.54)	68.36 (± 1.75)					
YM	74.57 (± 1.93)	60.52 (± 1.86)	56.64 (± 1.44)	54.61 (± 1.54)	68.41 (± 1.75)					
OF	79.80 (± 2.80)	76.80 (± 2.69)	69.90 (± 2.08)	62.80 (± 2.23)	72.85 (± 2.53)					
OM	86.00 (± 3.62)	76.67 (± 3.47)	73.04 (± 2.69)	70.54 (± 2.88)	84.25 (± 3.27)					
Heart Rate										
YF	73.57 (± 2.08)	67.49 (± 2.01)	66.21 (± 2.15)	90.30 (± 2.12)	76.83 (± 2.59)					
YM	68.10 (± 2.08)	61.80 (± 2.01)	61.04 (± 2.15)	81.42 (± 2.12)	64.27 (± 2.59)					
OF	74.50 (± 3.01)	69.30 (± 2.92)	69.70 (± 3.11)	86.55 (± 3.07)	78.60 (± 3.75)					
OM	66.50 (± 3.88)	59.58 (± 3.76)	56.38 (± 4.02)	71.00 (± 3.96)	66.00 (± 4.84)					

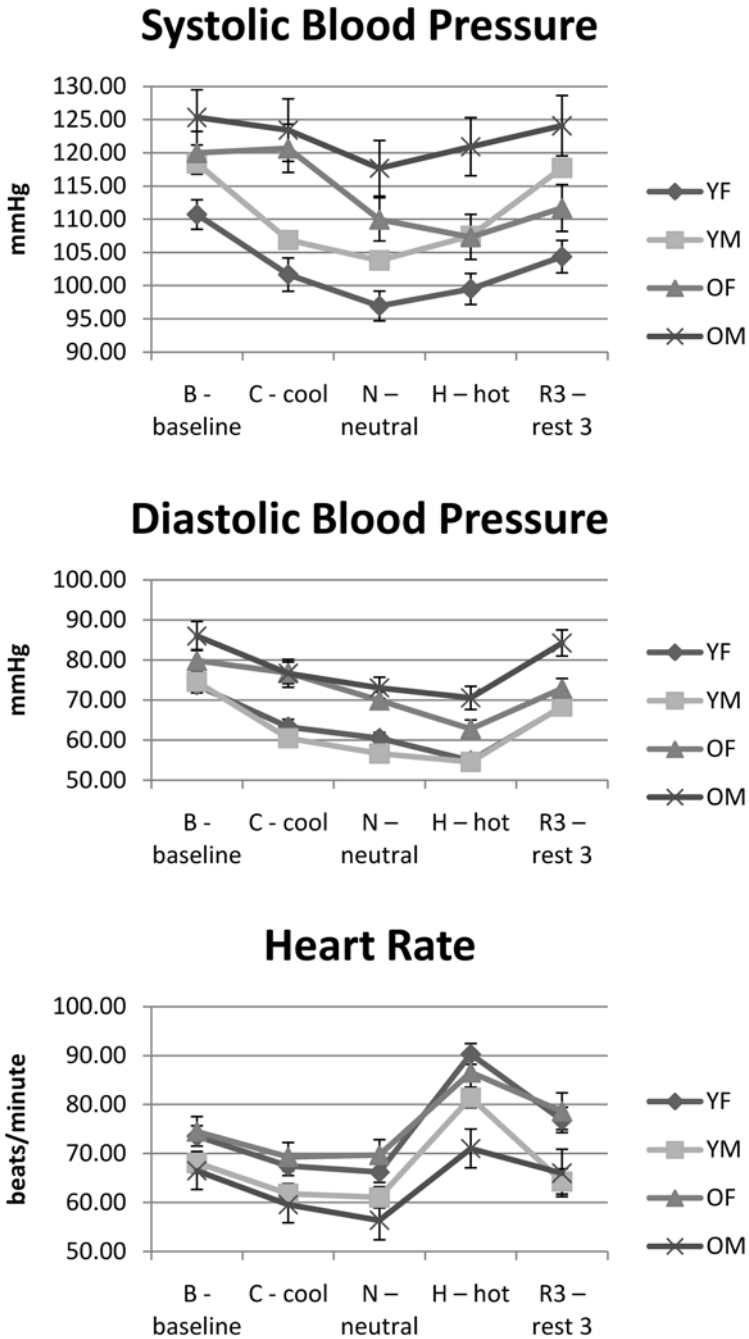


Figure 1 — Estimated marginal means and standard errors for all variables. (continued)

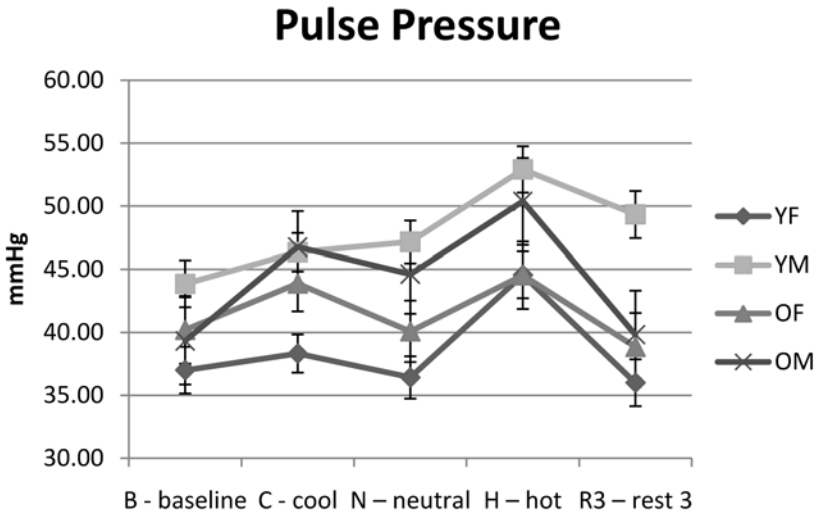


Figure 1 — (continued) Estimated marginal means and standard errors for all variables.

immersion and warm to recovery. From warm to recovery, there was a significant between-groups effect for the change scores, $F(3, 54) = 4.06, p = .01$, where older males ($M = -5.00, SD = 3.83$) significantly differed from younger males ($M = -17.15, SD = 8.66$), $p = .006$; older males had less decrease in heart values from warm to recovery compared to younger males.

Pulse pressure. The 4 (between groups: age/gender groups) \times 5 (within groups: immersion temperatures) mixed factorial ANOVA resulted in a significant between groups effect, $F(3, 54) = 8.76, p < .001$; a significant within-groups ANOVA, $F(4, 216) = 12.58, p < .001$; and a nonsignificant interaction, $F(12, 216) = 1.50, p = .13$. Estimated marginal means for all variables are presented in Table 2 and Figure 1D. Post hoc tests were performed across groups during the cool and warm immersions. In the cool immersion, there was a significant between-groups effect, $F(3, 54) = 5.38, p < .01$, where younger females ($M = 38.32, SD = 6.66$) had significantly lower pulse pressure values compared to younger males ($M = 46.35, SD = 6.51$), $p < .001$. In the warm immersion, there was a significant between-groups effect, $F(3, 54) = 4.23, p < .01$, where younger females ($M = 44.56, SD = 6.39$) had significantly lower pulse pressure values compared to younger males ($M = 52.90, SD = 10.51$) $p = .002$.

Discussion

This study was unique in that we sampled a convenience cross-section drawn from a healthy population with ages ranging from 18 to 65 years and both sexes to examine the effect of water immersion at three different temperatures. We found significant between-group and within-group interaction effects for SBP, DBP, and HR for age and sex during different water immersion temperatures.

Currently there are no studies to compare these results. Some researchers have looked at the effects of age and its relationship to temperature regulation in a dry environment using thermally controlled water inflated suits. In a review of literature examining age responses to temperature changes, increasing age is associated with an attenuated vasoconstrictor response during cold exposure. Age may be associated with a diminished skin blood flow response to both reflex vasodilation and baroreflexes directed toward the skin during heat stress (Kenney & Munce, 2003). These findings suggest that age-related changes in the structure and regulation of the peripheral vasculature necessitate modifications of the cardiovascular system's homeostatic control mechanisms.

In our study, older women had a significantly different SBP response from baseline to cool water than the YF and YM. It may be the responsiveness of the aging heart to temperature changes makes it more difficult to regulate heart rate, heart muscle contraction, and blood flow to the skin and visceral organs (Minson, Wladkowski, Cardell, Pawelczyk, & Kenney, 1998). These difficulties may affect the response of blood pressure to cool water immersion. In the current study, DBP decreased for all groups across immersion temperatures and remained lower at the end of the 12 minute rest compared to baseline. For OF the change in DBP between baseline to cool water immersion was significantly different from YM, indicating a possible age and sex interaction effect when immersed in cool water.

In the current study older individuals started out with slightly higher SBP and DBP but all groups saw a reduction in SBP and DBP after exiting from the warm water. Itoh et al. (2007) reported that SBP and DBP and total peripheral resistance were significantly higher in the elderly group compared to a younger group at xiphoid and navel water immersion levels. In the younger group, both SBP and DBP were not statistically different between water immersion levels (Itoh et al., 2007). Itoh tested male participants who were similar to the ages in the current study, but the younger males were competitive swimmers. Comparisons between the Itoh study and ours are only relevant at the chest immersion level where they found SBP and DBP did not differ significantly with immersion levels compared to baseline. The role that cardiovascular fitness levels of competitive swimmers played is unknown.

The temperature of the warm water immersion in the current study was 39° C. A study by Shin, Wilson, & Wilson, (2003) supported the results of the current study with water immersion at 40° C with older hypertensive and healthy control patients. The hypertensive subjects started off with a higher SBP and DBP, but both groups showed a substantial fall in SBP, but values returned near baseline after 5–10 minutes of immersion (Shin et al., 2003). Collectively, these data along with the results of the current study may imply that warm water immersion results in an increased diastolic filling and possible unloading of left ventricular volume during contraction (Cider et al., 2006).

It is more difficult to find comparable research on the role sex may play in BP response. When looking at the mean values of SBP and DBP, we found that BP response to water appears similar between YM and YF across a range of temperatures; however, there was a significant difference in PP in both cool and warm immersion between YF and YM. In a study by Watenpaugh et al. (2000), no sex differences in BP response were observed with water temperature ranging between 33-39° C. The researchers examined young male and female subjects and compared

non-immersed states and water immersed. With water immersion at 34.6° C for 3 hours they found no significant increases in MAP, SBP or DBP during the entire immersion time (Watenpaugh, Pump, Bie, & Norsk, 2000).

Weston, O'Hare, Evans, & Corrall (1987) reported no change in SBP with a range of immersion temperatures from 33-39° C, yet mean arterial pressure was decreased due to a fall in DBP at all immersion temperatures for both sexes (Weston, O'Hare, Evans, & Corrall, 1987). The authors hypothesized that the variation of temperature produces a complex series of changes under baroreceptor control. These results differ from the current study, but are likely due to methodological issues and population sample.

This study also gathered data on how blood pressure changed after all immersion sessions. All groups saw a decrease in SBP and DBP from baseline levels after exiting the warm water immersion temperature while PP declined from pre-immersion levels for females and increased for males. HR was elevated for females from baseline to exit from the warm water, while males both saw a slight decrease. No comparable research exists to corroborate these observations, but the effects on SBP and DBP upon leaving cool and neutral and warm water immersion may warrant further research. From the above literature comparisons, it is difficult to directly compare our results to any specific, prior study outcomes. We do feel our results offer clear and precise initial reporting of the impact sex and age upon BP and HR of individuals immersed to sternal notch depth at different immersion temperatures.

There is a great deal of difficulty in comparing previous research due to a lack of water immersion studies, variations in sample size, water temperatures, variables measured, and reporting of results. These data do provide a potential set of baselines against which future studies may compare.

Conclusion

This study is unique in that we tested a diverse collection of healthy adult participants of both sexes ranging in age between 18 and 65 years. The observations presented here focus on the effect on blood pressure and heart rate of three different water temperatures (31, 36, and 39° C) when participants are submerged to the sternal notch while sitting. We conclude healthy older women demonstrate a statistically significant different response to water immersion as compared to young females and both young and older males. If we see these trends in healthy populations, we also may see these effects in cardiovascularly-compromised individuals.

Future Directions

A limitation to this study was the variable cell sizes across the age/sex groups. Future research with equivalent cell sizes across the groups needs to verify the stability of these results. Understanding changes to BP during resting water immersion across different ages and both sexes presents clinical applications relevant to practitioners responsible for rehabilitation of cardiovascularly-compromised patients. As we develop new treatments involving water immersion, it is important to understand the effects of water immersion at different temperatures on the general population.

Examples might include running on an underwater treadmill recommended as a low impact cardiovascular treatment. Without knowing their baseline BP or the effects immersion temperatures may have on BP response could be detrimental to patients. Future research should examine the effects of water immersion at different temperatures and levels of BP during exercise.

References

- Arborelius, M., Jr., Balldin, U.I., Lilja, B., & Lundgren, C.E. (1972). Hemodynamic changes in man during immersion with the head above water. *Aerospace Medicine*, 43(6), 592-598.
- Asahina, M., Asahina, M.K., Yamanaka, Y., Mitsui, K., Kitahara, A., & Murata, A. (2010). Cardiovascular response during aquatic exercise in patients with osteoarthritis. *American Journal of Physical Medicine and Rehabilitation*, 89(9), 731-735.
- Begin, R., Epstein, M., Sackner, M.A., Levinson, R., Dougherty, R., & Duncan, D. (1976). Effects of water immersion to the neck on pulmonary circulation and tissue volume in man. *Journal of Applied Physiology*, 40(3), 293-299.
- Bonde-Petersen, F., Schultz-Pedersen, L., & Dragsted, N. (1992). Peripheral and central blood flow in man during cold, thermoneutral, and hot water immersion. *Aviation, Space, and Environmental Medicine*, 63(5), 346-350.
- Christie, J.L., Sheldahl, L.M., Tristani, F.E., Wann, L.S., Sagar, K.B., Levandoski, S.G., Ptacin, M.J., Sobocinski, K.A., & Morris, R.D. (1990). Cardiovascular regulation during head-out water immersion exercise. *Journal of Applied Physiology*, 69(2), 657-664.
- Cider, A., Svealv, B.G., Tang, M.S., Schaufelberger, M., & Andersson, B. (2006). Immersion in warm water induces improvement in cardiac function in patients with chronic heart failure. *The European Journal of Heart Failure*, 8, 308-313.
- Franklin, S.S., Gustin, W., Wong, N., Larson, M.G., Weber, M.A., Kannel, W.B., et al. (1997). Hemodynamic patterns of age-related changes in blood pressure: The Framingham Heart Study. *Circulation*, 96, 308-315.
- Gabrielsen, A., Johansen, L.B., & Norsk, P. (1993a). Central cardiovascular pressures during graded water immersion in humans. *Journal of Applied Physiology*, 75(2), 581-585.
- Gabrielsen, A., Johansen, L.B., & Norsk, P. (1993b). Central cardiovascular pressures during graded water immersion in humans. *Journal of Applied Physiology*, 75(2), 581-585.
- Gabrielsen, A., Warberg, J., Christensen, N.J., Bie, P., Staegeger, C., Pump, B., & Norsk, P. (2000). Arterial pulse pressure and vasopressin release during graded water immersion in humans. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology*, 278, R1583-R1588.
- Hildenbrand, K., Becker, B., Whitcomb, R., & Sanders, J.P. (2010). Age dependent autonomic changes following immersion in cool, neutral, and warm water temperatures. *International Journal of Aquatic Research & Education*, 4(2), 127-146.
- Itoh, M., Fukuoka, Y., Kojima, S., Araki, H., Hotta, N., Sakamoto, N., Nishi, K., & Ogawa, H. (2007). Comparison of cardiovascular autonomic responses in elderly and young males during head-out water immersion. *Journal of Cardiology*, 49(5), 241-250.
- Kenney, L.W., & Munce, T.A. (2003). Invited Review: Aging and human temperature regulation. *Journal Applied Physiology*, 95, 2598-2603.
- Minson, C.T., Wladkowski, S.L., Cardell, A.F., Pawelczyk, J.A., & Kenney, L.W. (1998). Age alters the cardiovascular response to direct passive heating. *Journal Applied Physiology*, 84 (4), 1323-1332.
- Miwa, C., Sugiyama, Y., Iwase, S., Mano, T., Ohira, Y., Grigoriev, A., Kozlovskaya, I., Egorov, A., & Shenkman, B. (1997). Effects of three days of dry immersion on heart rate and blood pressure variabilities during head-up tilting in humans. *Environmental Medicine*, 41(2), 135-137.

- Miwa, C., Sugiyama, Y., Mano, T., Iwase, S., & Matsukawa, K. (1997). Sympatho-vagal responses in humans to thermoneutral head-out water immersion. *Aviation, Space, and Environmental Medicine*, 68(12), 1109-1114.
- Nishimura, M., & Shoonodera (2001). Effects of water temperature on cardiac autonomic nervous system modulation during supine floating. *Journal of Gravitational Physiology*, 8(1), 65-66.
- Park, K.S., Choi, J.K., & Park, Y.S. (1999). Cardiovascular regulation during water immersion. *Applied Human Science: Journal of Physiological Anthropology*, 18 (6), 233-241.
- Shin, T.W., Wilson, M., & Wilson, T.W. (2003). Are hot tubs safe for people with treated hypertension? *Canadian Medical Association Journal*, 169(12), 1265-1268.
- Sramek, P., Simeckova, L., & Jansky, L. (2000). Human physiological responses to immersion into water of different temperatures. *European Journal of Applied Physiology*, 81, 436-442.
- Ueno, L. M., Miyachi, M., Matsui, T., Takahashi, K., Yamazaki, K., Hayashi, K., Onodera, S., & Moritani, T. (2005). Effect of aging on carotid artery stiffness and baroreflex sensitivity during head-out immersion in man. *Brazilian Journal of Medical and Biological Research*, 38, 629-637.
- Watenpaugh, D.E., Pump, B., Bie, P., & Norsk, P. (2000). Does gender influence human cardiovascular and renal responses to water immersion? *Journal Applied Physiology*, 89, 621-628.
- Weston, C.F.M., O'Hare, J.P., Evans, J.M., & Corrall, R.J.M. (1987). Haemodynamic changes in man during immersion in water at different temperatures. *Clinical Science*, 73, 613-616.