Title: Influence of gender on resting cardiovascular parameters of apparently healthy adults on land and in water

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Abstract

Background: The hydro-pool is widely used for health promotion and rehabilitation, yet information regarding resting cardiovascular responses of male and female adults to acute water immersion is scarce.

Objective: This study evaluated gender influence on resting Mean Arterial Pressure (MAP), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) and pulse rate of apparently healthy adults during acute water immersion in erect standing (ES) at xiphisternum level.

Methods: 193 healthy adults (96 males and 97 females) who were non-regular swimmers participated in this study. Participants' Body Mass Index (BMI) was calculated using their height and body weight measured on land. The SBP, DBP and pulse rate were measured on land and in the hydro-pool after 2 to 3 minutes of immersion using an electronic blood pressure monitor. The MAP was calculated using the formula: MAP= DBP+ (SBP-DBP/3). Data were analysed using paired sampled *t* test and mixed design two-way ANOVA at $p<0.05$.

Results: Participants' ages ranged between 18 and 38 years (mean age = 22.4±2.7 years). The BMI of male and female participants were not significantly different. Male and female groups experienced significant reductions in MAP (5.9mmHg vs 4.9mmHg), DBP (7.7mmHg vs 5.4mmHg) and pulse rate (4.4bpm vs 8.1bpm), respectively, during water immersion. However, SBP on land and during water immersion for both groups were not significantly different. There were significant main effects for all the cardiovascular parameters measured but significant interraction effects (environment x gender) were found for MAP and SBP only.

Conclusion: Human cardiovascular responses to acute immersion in a hydro-pool is influenced by gender with respect to MAP and SBP. This should always be considered during hydrotherapy.

Key Words: Arterial Pressure; Body Mass Index; Gender; Standing; Hydrotherapy.

Introduction

The hydro-pool has a wide range of applications, including recreation, medical rehabilitation and as a research tool for studying human cardiovascular physiology during water immersion. The use of the hydro-pool for these purposes is attributed to the biophysical properties of water, such as bouyancy, hydrostatic pressure, relative densities and thermodynamics (Becker, 2009). These unique properties could elicit a series of physiological responses that have profound clinical implications for human cardiovascular and musculoskeletal systems (Ward et al, 2005; Stark, Rudell, and Huas, 2008; Irion, 2009). Most investigations in this field have concentrated largely on cardiovascular responses of men to immersion in water despite the possibility that cardiovascular responses of male and female subjects may differ during water immersion as do gender responses to other physiological stimuli.

Many reasons have been given for the more frequent enrollment of men into studies that focus on physiological response in water. Such reasons were avoidance of the effects of menstruation in women, which might interfere with the outcome of the study. In some cases, women are not included in the studies because of their anatomical structures, and historical, religious and cultural beliefs in some settings (Akerkar, 2001). Another reason is the perception that women require more elaborate preparation before and after immersion (Watenpaugh et al, 2000).

Mannino & Kaufman (1986) reported the occurence of equal episodic horripilation in both men and women following aerobic exercise at immediate post 20-minute leg immersion in water at 16^{o}C, but this related significantly to torso skin temperature in men and percent body fat in women over the range of torso skin temperature tested. The authors also recorded significant reduction in core temperature (37^{o}C to 36.6^{o}) in men at 34^{o}C torso skin temperature but this remained unchanged in women. White, Gotshall, and Tucker (1996) compared lower body negative pressure (LBNP) tolerance of male and female individuals before and after 6 hours of water immersion and after 6 hours of bed rest and reported equivalent reductions in LBNP tolerance for both genders after immersion, while the female group showed lower tolerance than males after 6 hours of bed rest. Another study investigating gender influence on renal and cardiovascular responses to 3 hours of water immersion found no gender difference in arterial pressure and heart rate. However, it was found that women significantly excreted greater urodilatin than men, while men excreted more potasium than women following the same immersion period (Watenpaugh et al, 2000). Immersion of apparently healthy male and female adults at water temperatures of 20^{o}C and 28^{o}C indicated greater decreases in rectal temperature in women than men at rest and during moderate exercise while they also maintained a higher rectal temperature at 28^{o}C with more intense exercise (McArdle et al, 1992).

Investigating cardiovascular responses of male and female individuals during immersion is important because of the differences in physiological compositions between the two genderes. These include size-dependent factors such as fat composition, height, and lean body mass and size-independent factors such as lower body negative pressure and simulated orthostasis (Hordinsky et al, 1981). The present study was designed to determine the difference in the mean arterial presure (MAP), systolic blood pressure (SBP), diastolic blood pressure (DBP) and pulse rate during acute water immersion in erect standing for 2 - 3 minutes between male and female adults. We hypothesized that both male and female participants would not differ significantly in these selected parameters during immersion in water.

Methods

Participants

Participants in this study were healthy university undergraduates who were recruited through a purposive sampling technique. They were eligible for inclusion if they were non-regular swimmers, had no history of clinical conditions that could be made worse during immersion, were not under any medication that could affect their wakefulness in the pool and were 18 years of age and above. Participants with open wounds, skin rashes, hypertension or hypotension and female participants undergoing menstration on the day of water immersion were excluded from the study. Proportional stratified sampling was adopted to ensure equal numbers of male and female participants. The minimum sample size of the participants was estimated using the formula**:**

$N = 4\sigma^2 (Z_{crit} + Z_{pwr})^2 \div D^2$ (Eng, 2003).

The Z_{pwr} was 0.842 at 0.80 statistical power.

Procedure

Approval for the study's protocol was obtained from the Ethics Committee of the School of Allied Health Sciences, College of Health Sciences, University of Ghana. Participants were briefed about the procedure of the study after which they consented to participate. They were screened for limb length discrepancy that might interfere with symmetrical stepping on the weighing scale during body weight measurement, hypotension and hypertension on land while the skin was visually inspected to rule out infection. Study participants were further interviewed to screen for other exclusion criteria such as presence of medical or neurological pathologies and ongoing menstration (in female participants).

Protocols

The format for the measurement procedures was standardized on land and in water. All participants dressed in light swimming costumes while female participants were also provided with swimming caps. Participants' blood pressure was measured on land using an electronic blood pressure monitor (Digital Model OB11-111, San Diego, CA, USA). During the pilot study, good agreement was found between the readings from the automated digital blood pressure monitor and a conventional sphygmomanometer (r=0.95). Cronbach alpha values for the digital blood pressure monitor were also given as 0.94, 0.93, 0.96 for pulse, DPB, and SBP, respectively. Each participant was required to stand still in erect posture on land with the left upper limb elevated and supported horizontally at 90^o of abduction by one of the research assitants. With the head and trunk in erect position, the participants kept their right upper limb by their sides. In compliance with the ideal hydrotherapy unit's requirement for ensuring a comfortable environment, the room temperature during the land measurement was approximately 27°C.

Participants prepared for the water immersion session by showering and toileting and maintained the same dress worn during measurements on land. Measurements were taken at the same period of the day (1p.m-4p.m) for every subject to ensure similar environmental temperature. Participants were immersed to the level of xiphisternum in erect standing posture; the correct immersion level for short participants was by standing on weighted wooden platforms. Blood pressure and pulse rate were measured within two to three minutes, in the same posture as

performed on land with the monitor held at heart level and above the water surface. MAP was calculated using the following formula MAP= DBP+ (SBP-DBP/3).

The procedure adopted was based on the protocol described in a previous study (Ward et al, 2005). The choice of immersion temperature conformed to the critical temperature defined as the water temperature range that a subject can tolerate at rest for two hours without shivering during water immersion (Iwamoto et al, 1988; Becker, 2009). The average water temperature for this study was 29C^{o}, as measured by the pool attendants during the research after every hour. This falls within the critical hydro-pool temeprature range (26C^{o} to 35.5C^{o}).

Data analysis

Data generated were analyzed using the Statistical Package for Social Sciences (SPSS Inc., 2007) version 16.0. Descriptive statistics of mean and standard deviation were used to summarize the data. Paired sampled *t*-test was used for within-group comparison to compare MAP, SBP, DBP and pulse on land and in water for male and female participants. A mixed design two-way ANOVA was used to determine whether there were significant differences between environment (air and water) and genderes, and whether there was a significant interraction between environment and gender for the selected cardiovascular parameters. The level of significance was set at $p<0.05$.

Results

One hundred and ninety-three healthy adults (96 males; 97 females) participated in this study. The age of the subjects ranged from 18 to 40 years (mean age= 22.4±2.7 years). Male and female groups were not significantly different *(p*=0.109) in their body mass index (BMI). Using WHO classification, 23 of the participants (0.11%) were overweight, 7 (0.03%) were obese while the rest, 163 (99.86%), were of normal body weight. The participants' mean BMI was 22.1±3.3 Kg/m^2. However, male participants were older and taller, and weighed significantly more than the female participants (Table 1).

Table 1: Physical characteristics of the participants on land

Variable	**Male (n=96) X±SD**	**Female (n=97) X±SD**	**Total (193) X±SD**	***t*-value**	***p*-value**
Weight (kg)	62.8±10.7	58.6±9.7	60.7±10.4	2.8	0.003
Height (m)	1.7±0.1	1.6±0.1	1.6±0.1	9.2	<0.001
Age (years)	23.1±32	21.3±1.9	22.4±2.7	3.4	<0.001
BMI (kg/m2)	21.7±3.3	21.3±1.9	22.1±3.3	-1.6	0.109

Table 2: Paired t-test comparison between resting cardiovascular parameters on land and in water for male and female participants

Parameter	**Male**			**Female**		
	On land	**In water**	***p***	**On land**	**In water**	*p*
MAP (mmHg)	98.0±10.5	92.0±13.6	0.001	91.0±10.2	86.0±17.4	0.04
SBP (mmHg)	131.0±14.8	129.0±17.1	0.272	121.0±13.5	117.0±21.6	0.058
DBP (mmHg)	81.0±9.8	73.0±14.5	<0.001	76.0±9.8	71.0±16.5	0.001
Pulse rate (bpm)	77.0±15.7	73.0±4.4	0.02	83.0±13.1	75.0±14.9	<0.001

Key: MAP= Mean arterial pressure; SBP= Systolic blood pressure; DBP= Diastolic blood pressure

Resting cardiovascular parameters for male and female participants on land and in water are presented in Table 2. Male and female groups experienced significant reductions in MAP (5.9mmHg vs 4.9mmHg), DBP (7.7mmHg vs 5.4mmHg) and pulse rate (4.4bpm vs 8.1bpm), respectively, during water immersion. However, there were no significant differences (p>0.05) between SBP on land and in water for both groups. The results of the mixed design 2-way ANOVA are presented in Table 3. There were significant main effects for all the cardiovascular parameters between male and female participants but significant interaction effects (environment x gender) during immersion were found for MAP and SBP only.

Table 3: Comparison of the selected cardiovascular parameters for male and female participants on land and during acute water immersion

Source	**Type III sum of square**	**Mean square**	**F**	***p***
MAP (Environment)				
Water	1537011.26	1537011.26	1.59E4	<0.001
Air	1730485.04	1730485.04	6.26E3	<0.001
Error	20710.21	108.4		
MAP (Environment x Gender)				
Baseline	1993.42	1993.42	18.38	<0.001
Immersion	1438.46	1438.46	5.86	0.016
Error	46849.65	245.28		
SBP (Environment)				
Water	2932410.66	2932410.66	7.66E3	<0.001
Air	3083438.14	3083438.14	1.52E4	<0.001
Error	73052.08	382.47		
SBP (Environment x Gender)				
Baseline	6124.93	6124.93	16.01	<0.001
Immersion	4487.48	4487.48	22.25	<0.001
Error	38507.27	201.60		
DBP (Environment)				
Water	1006871.21	1006871.21	4.15E3	<0.001
Air	1199534.13	1199534.13	1.23E4	<0.001
Error	46309.51	242.45		
DBP (Environment x Gender)				
Baseline	315.40	315.40	1.30	0.255
Immersion	1120.72	1120.72	11.52	0.001
Error	18579.80	97.27		
Pulse (Environment)				
Water	1066639.44	1066639.44	5.04E3	<0.001
Air	125444.20	125444.20	5.97E3	<0.001
Error	40362.64	211.32		
Pulse (Environment x Gender)				
Baseline	169.10	169.10	0.80	0.372
Immersion	1490.46	1490.46	7.09	0.008
Error	40140.31	210.15		

Key: MAP= Mean arterial pressure; SBP= Systolic blood pressure; DBP= Diastolic blood pressure

Discussion

The main focus of this study was to compare the changes in the cardiovascular parameters of healthy male and female individuals during water immersion to the xiphisternum level in erect standing for between 2 - 3 minutes. The results of the study showed significant main effects and interraction effects (environment x gender) during immersion for MAP and SBP only. The main interraction effects for DBP and pulse rate were not significantly different between the male and female participants. Our hypothesis that there would be no significant difference in the selected cardiovascular parameters of male and female participants during immersion in water was therefore rejected for MAP and SBP but accepted for DBP and pulse rate for both groups. This finding suggests that gender differences should be considered with respect to anticipated changes in MAP and SBP while planning rehabilitation and recreation programmes in the hydro-pool, particularly within the first two to three minutes of immersion.

Our findings are not in agreement with the report by Watenpaugh et al (2000), who reported that gender had no effect on arterial pressure during a 3-hour water immersion. The study protocol in both studies may be an important factor to consider. The participants in the previous study were immersed for three hours in a sitting position, while those involved in this study performed acute immersion at rest in an erect standing posture for only 2 - 3 minutes. These different findings may imply that cardiovascular changes of male and female individuals following initial water immersion do not totally follow the same physiological trend. A previous study has identified the duration of water immersion as being crucial to the human cardiovascular parameters'responses to water immersion. For instance, Ward et al (2005), compared pre-immersion, initial immersion, post-exercise immersion and post-immersion cardiovacular parameters of pregnant women who undertook non-aerobic aquatic physiotherapy and found significantly lower systolic and diastolic blood pressures and MAP following acute immersion in the pool compared to pre-immersion values. The focus of the present study was, however, to examine the pattern of immediate or acute human response to water immersion.

Given the greater hydrostatic pressure of water than air, it can be theorized that the venous return would be greater in water, hence the central venous pressure and end-diastolic volume (EDV) will be greater with consequent increase in stroke volume and lowering of the heart rate. In this study, the pulse pressure in men increased, thus reflecting a greater stroke volume, but remained virtually unchanged in women. This may suggest some level of gender-related differences in cardiovascular responses to water immersion, which was also suggested by the significant interaction effect between environment and gender for the MAP and SBP. Further, the lower diastolic pressure in water than on land could be attributed to a reduction in total peripheral resistance secondary to skin vasodilation.

Clinical implications

Immersion in therapeutic hydro-pools is utilized by physiotherapists to facilitate bouts of strenuous exercise among athletes (Wilcock, 2005), ensure fetal descent in pregnant women during the process of labour (Stark, Rudell, and Huas,2008) and encourage gradual weight bearing after total knee or hip arthroplasty (Gianquito, Ciotola, and Margutti, 2007). The outcome of this study hence has implications for physiotherapists in clinical practice when designing preliminary aquatic rehabilitation for patients either at rest or during physical activities. Cardiovascular parameters, especially for women, should be monitored as early as the first few minutes of immersion in water.

Study Limitation and Recommendation for Future Research

An obvious limitation of this study is our failure to monitor the cardiovascular changes beyond the three minutes of immersion since the length of immersion has been identified as a possible determinant of human circulatory adjustments during immersion in water. Future studies should hence investigate the gender effect of prolonged immersion in water as practiced during hydrotherapy procedures.

Conclusion

Finding in this study revealed that human cardiovascular response to acute immersion in a hydro-pool is influenced by gender with respect to MAP and SBP. This should always be considered during hydrotherapy.

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Conflict of interest: None declared.

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