International Journal of Aquatic Research and Education

Volume 12 | Number 4 | Article 13

5-27-2020

Cardiovascular and Stride Frequency Differences During Land and Aquatic Treadmill Walking

Jessica Burton
The University of Alabama in Huntsville, jb0223@uah.edu

Sarah Duffey
The University of Alabama in Huntsville, sduffey23@gmail.com

Amber Hammonds
The University of Alabama in Huntsville, arh0045@uah.edu

Anna LeDuc
The University of Alabama in Huntsville, aml0028@uah.edu

Rachel Shumate
The University of Alabama in Huntsville, rls0037@uah.edu

See next page for additional authors

Recommended Citation

Burton, Jessica; Duffey, Sarah; Hammonds, Amber; LeDuc, Anna; Shumate, Rachel; Coons, John; and Conners, Ryan T. (2020) "Cardiovascular and Stride Frequency Differences During Land and Aquatic Treadmill Walking," *International Journal of Aquatic Research and Education*: Vol. 12: No. 4, Article 13.
DOI: https://doi.org/10.25035/ijare.12.04.13
Available at: https://scholarworks.bgsu.edu/ijare/vol12/iss4/13

Cardiovascular and Stride Frequency Differences During Land and Aquatic Treadmill Walking

Cover Page Footnote

The authors thank all of the participants for their efforts during the study.

Authors

Jessica Burton, Sarah Duffey, Amber Hammonds, Anna LeDuc, Rachel Shumate, John Coons, and Ryan T. Conners

Abstract

This study examined heart rate (HR) and stride frequency (SF) values of 30 college-aged males and females during dry-land (DL) and aquatic walking (AW). Aquatic walking trials were completed in an underwater treadmill with the water depth at waist level; the water temperature (31℃ ± 0.1℃) and room temperature (26.6℃ ± 0.1℃) were maintained at thermoneutral levels throughout the study. During each walking condition, HR and SF were recorded at treadmill speeds of 1 mph, 2 mph, and 3 mph. Participants were instructed to walk with their hands at their sides swinging as they would when walking on dry-land unless they felt the need to use the handrails to steady themselves. Heart rate monitors were used to record cardiovascular changes, and strides were measured from consecutive left and right toe strikes. Results of the study indicated HR was significantly higher during DL than AW at 1 mph ($p < .001$) and 3 mph ($p < .001$) but was not significantly different ($p = .64$) at 2 mph. The SF of the participants was significantly lower ($p < .001$) during AW than DL at all speeds. When comparing sex, females had significantly higher HR at 1 mph ($p = .012$), 2 mph ($p = .007$), and 3 mph ($p < .001$) than males for DL conditions. No differences in HR were found during the AW conditions ($F = 0.66$, $p = 0.44$, $\eta_p^2 = 0.02$). No differences in SF were observed between males and females in both DL ($F = 2.96$, $p = 0.06$, $\eta_p^2 = 0.09$) and AW ($F = 1.03$, $p = 0.32$, $\eta_p^2 = 0.036$) conditions. As a result, AW increased HR values similar to those of DL, but without the added stress to the lower extremities due to the buoyancy of the water. Thus, AW provided an exercise medium capable of meeting the ACSM intensity guidelines for PA and allowed adults to be physically active presumably with less stress on the lower body.

Keywords: college students, heart rate, stride frequency, treadmill walking, underwater treadmill

Introduction

Engaging in physical activity (PA) has been linked to many health benefits (Hamer & Chida, 2008; Hamer et al., 2012; Peacock et al., 2014). Specifically, walking can develop and maintain cardiovascular fitness as well as give individuals a sense of independence. Because of its simplicity, ready availability, and affordability, walking is an exercise mode that is easily accessible for most individuals.

Due to the positive correlation between heart rate (HR) and exercise intensity, HR can be used as a practical measure of exercise intensity. Stride frequency (SF) also plays a valuable role in measuring walking exercise because an increased stride frequency has been shown to increase the intensity of PA. Values for HR and SF can be affected by previous injuries, sedentary behavior, chronic illness, biological differences between males and females, and psycho-emotional factors.

Injuries or medical issues like those previously mentioned may hinder individuals from meeting the exercise guidelines developed by the American College of Sports Medicine (ACSM) (ACSM, 2000). As injuries and medical issues that limit exercise on land have increased, aquatic exercise (AE) has become a more popular exercise modality. Aquatic exercise is a form of cardiorespiratory exercise that has been shown to reduce stress in the lower extremities and to reduce overuse injuries (Masumoto et al., 2007b; Schaal, et al., 2012). During AE, stress placed on the joints during ground impact is reduced due to the buoyancy of water supporting the person's body mass (Schaal, et al., 2012; Silvers et al., 2007). Ground reaction forces are decreased further as the body is immersed deeper into the water (Barela et al., 2006; Fontana et al., 2011; Haupenthal et al., 2010, Haupenthal et al., 2013; Roesler et al., 2006) which should further decrease the amount of stress placed on an individual's joints. Because of the decrease in the amount of stress placed on the body, AE is utilized to treat injuries, post-surgical procedures, and chronic medical conditions (Jung et al., 2018). Another benefit of AE is an increased float phase while walking due to the resistance water provides because of hydrostatic pressure. An increased float phase allows individuals to slow down their walking biomechanics and focus on controlling their movements (Cadenas-Sanchez, et al., 2015). Additionally, the hydrostatic pressure of the water helps to direct blood back to the heart, increasing venous return and cardiac output (Stevens & Morgan, 2010). Thus, AE can be beneficial for those individuals who have cardiovascular issues because it allows an individual to maintain a level of exercise intensity in the water at a lower overall heart rate (Conners et al., 2014). Aquatic walking (AW) can elicit improvements in aerobic fitness and may be a viable alternative to maintain and/or improve fitness levels in healthy and injured individuals (Masumoto, et al., 2013; Silvers et al., 2007).

Aquatic walking on an underwater treadmill has been shown to reduce SF when compared to dry-land (DL) treadmill walking in healthy older adults (Jung, et al., 2018). While similar studies have indicated that HR values during AW were higher than traditional dry-land walking HR values, studies also have suggested that HR values during DL conditions may be higher than HR values during AW conditions (Greene et al., 2011; Hall et al., 2004). Heart rate and SF values also have been compared between older individuals and younger individuals (Masumoto et al., 2007a); however, a lack of information exists regarding cardiovascular and SF differences during AW in college-aged individuals. Therefore, the aim of this study was to compare HR and SF of college-aged males and females during DL and AW on treadmills. We hypothesized that HR values would be higher during AW than HR values during similar speeds at DL conditions and expected SF values would be higher during DL walking conditions. We also hypothesized that males would have lower HR and SF values compared to females while performing both DL and AW.

Method

Participants

As approved by the University's Institutional Review Board (IRB), thirty healthy participants (15 males/15 females) provided informed consent and completed a physical activity readiness questionnaire (PAR-Q) which was reviewed by the researchers prior to testing. No previous training was necessary for individuals to be able to participate in this study; however, college athletes and individuals with similar exercise habits were excluded from this study. Excluding athletes from the study allowed us to more accurately represent how a healthy college-aged sample might perform. Body mass index (BMI) for each participant was calculated to determine baseline values for both male and female participants (see Table 1). Females averaged higher BMI values compared to males; however, RHR levels indicated that only a small difference in the level of cardiovascular fitness existed amongst the participants (see Table 1).

In addition to initial fitness level, the clothing choice worn while performing DL and AW can impact the amount of resistance while walking (Haupenthal et al., 2013). While most materials do not provide much resistance while moving through air, the same materials potentially could provide an increased amount of drag resistance in water which could alter the results of a study. As a result, participants were asked to wear the same tee shirt and athletic shorts, not of any particular material, but a clothing option that would not provide a large amount of drag resistance during each walking condition. If the participants did not wear the same exact same clothing for both trials they were excluded from the study. Participants were also excluded if they had previous lower body injuries, were not able to walk without aid, or had a fear of water (Cadenas-Sanchez, et al., 2015). Compliance for the study was 100%, with all participants completing each of the three speed trials for the two conditions (DL vs. AW) on two separate days with at least 24 hours rest in-between each condition.

Protocol

For confidentiality purposes, each participant was assigned an identification (ID) number 1-30 before data collection occurred. Following randomization of participant ID numbers, each participant was then randomly assigned to which condition would be completed first (DL or AW) with at least a minimum of 24 hours between the two conditions. Participants were asked not to consume caffeine at least twelve hours prior to participation and were instructed to perform both walking conditions while barefoot to insure there was no additional drag resistance

Table 1
Participant Characteristics

Variable	*M* ± *SD*
Height (cm)	170.1 ± 10.0
Weight (kg)	76.1 ± 14.7
Sex (male/female)	15/15
Age	22 ± 1
RHR (bpm)	90 ± 14
Male BMI (kg/m^2)	24.6 ± 3.9
Female BMI (kg/m^2)	27.9 ± 4.9

Note. M ± *SD* = mean ± standard deviation; RHR = resting heart rate; BMI = body mass index.

(Rife, 2008). After consent was obtained, participants' anthropometric measures were taken for height, weight, and resting heart rate (RHR).

During the initial testing session, each participants' height was measured to the nearest 0.25 cm using a Seca 217 stadiometer (Hanover, MD) and participants' weight (without shoes) was measured to the nearest 0.1 kg using a Seca 869 flat digital scale (Hanover, MD) (Conners et al., 2014). Following height and weight measurements, each participant sat in a dark room for five minutes. After the five minutes were up, resting heart rate (RHR) was taken via a Polar Heart Rate Monitor (Polar, USA) (Conners et al., 2014; Schaal et al., 2012). The participants also wore HR monitors while performing each of the two walking trial conditions.

Protocol for the DL and AW trials were adapted from previous studies performed by Masumoto et al. (2004; 2005; 2007a; 2007b). For the AW trials the water depth was at waist level, water temperature was consistently set at 31℃ ± 0.1℃, and the room temperature was set at 26.6℃ ± 0.1℃ (Masumoto et al., 2007b). These temperatures were used because they were considered to be thermo-neutral temperatures and would not skew the HR values during data collection. Prior to testing each condition, the participants had an opportunity to get accustomed to the equipment by completing a two-minute warm-up session at 1 mile per hour (mph) in the underwater treadmill with water in the chamber and without (Ferno, Wilmington, OH) (Oeveren et al., 2017). The underwater treadmill utilized consisted of a control panel, a water reservoir and filtration system, and large plexiglass windows to allow the supervision of each participant (Conners et al., 2014). The concept of an underwater treadmill is relatively similar to that of a DL treadmill. The belt is propelled by internal mechanisms. The model of underwater treadmill used in this study does have the ability to alter incline. In the study, speed was the only factor that was manipulated and the jets of the treadmill were not utilized to provide additional resistance.

The walking protocol under each condition consisted of walking at one mph for three to five minutes to represent slow speed, two mph for three to five minutes to represent moderate speed, and three mph for three to five minutes to represent fast speed (McNarry et al., 2017). Each participant's time may have varied slightly due to the length of time it took them to achieve steady state; however, all of the participants were able to achieve steady state within three to five minutes at each speed because the exercise was not considered hard or strenuous. Prior to testing, all treadmill speeds were verified for validity ([belt length x number of revolutions] / time measured) in both the dry-land and aquatic conditions. The speeds that were used in this study differed slightly from Masumoto's research due to a younger population of participants who were tested. During each minute of the walking trials, the participants' HR was collected from the HR monitors and a rest period of three minutes was allowed after the participant completed the walking speed trial for 1 mile per hour and 2 miles per hour (Masumoto et al., 2007b). While walking, researchers counted SF with a pitch counter for both AW and DL trials (see Photograph 1). Each stride was counted after a completion of one left and right step (Oeveren et al., 2017). Following the three speed trials, the participant completed a two-minute cool-down session for a safe progressive return to baseline values.

For the DL trial, participants walked on the same treadmill used during the AW trials without water in the chamber. No RHR or anthropometric values were recorded for the participants if the AW trial had previously been completed; however, the participants did follow the same protocol as the AW trial.

Statistical Analyses

All statistical analyses were completed using the Statistical Package for Social Sciences (SPSS) version 25. Means and standard deviations of participants are presented in Table 1. Six paired sample *t*-tests were used to compare differences in HR and SF during matched speed DL and AW trials. For the significant results, effect size was calculated using Cohen's *d* for paired sample t-tests (see Table 2). The interpretation of the ES for the paired-sample *t* tests were based upon the guidelines by Cohen (1988) (.01 = small, .06 = moderate, .14 = large effect). Two, three-way repeated measure analysis of variances (ANOVAs) were used to compare HR and SF values between males and females during DL and AW trials.

Photograph 1

Participant walking in the underwater treadmill

A violation of sphericity was noted during DL and AW trials while measuring HR and during AW while measuring SF. A Huynh-Feldt correction was used to examine the interaction between sex and the noted violations of sphericity. Independent samples t-tests were used as post-hoc analyses for the significant results. A Cohen's *d* for independent-samples t-test was used to measure effect size for significant post-hoc findings (Cohen, 1988) (see Table 3). Interpretations of ES magnitudes were based on the scale describe by Hopkins (2009) (< 0.2 = trivial, 0.2 - 0.6 = small, 0.6 - 1.2 = moderate, 1.2 - 2.0 = large. The alpha level was set at $p \leq 0.05$ for each test.

Results

Heart rate was significantly lower while walking at 1 mph in water, when compared to walking at the same speed on DL ($p < .001$). No significant differences were found for HR at 2 mph ($p = 0.635$) when DL and AW values were compared. While

DOI: https://doi.org/10.25035/ijare.12.04.13

walking at 3 mph in an aquatic exercise medium, HR was significantly higher compared to walking at 3 mph in the DL condition ($p < .001$). Aquatic walking resulted in significantly lower SF values at all three speeds when compared to walking at the same speeds in the DL exercise medium ($p < .001$). All AW and DL walking performance values are presented in Table 2.

Table 2

Dry-land and Aquatic Walking Performance Variables

Variable	Dry ($M \pm SD$)	Wet ($M \pm SD$)	P-value	η_p^2	Effect Size
HR @ 1 mph	100.9 ± 12.5	92.8 ± 10.8	< 0.001*	0.38	L
HR @ 2 mph	105.7 ± 12.4	106.4 ± 9.6	0.635	0.01	S
HR @ 3 mph	118.6 ± 15.9	141.2 ± 14.9	< 0.001*	0.08	M to L
SF @ 1 mph	185.8 ± 21.3	142.8 ± 17.0	< 0.001*	0.83	L
SF @ 2 mph	252.5 ± 19.0	200.6 ± 17.0	< 0.001*	0.89	L
SF @ 3 mph	301.7 ± 16.2	254.3 ± 25.7	< 0.001*	0.82	L
HR Recovery After 1 mph	96.5 ± 11.8	87.2 ± 11.3	< 0.001*		
HR Recovery After 2 mph	97.2 ± 12.2	87.4 ± 12.8	< 0.001*		

Note. $M \pm SD$ = mean ± standard deviation; HR = heart rate; SF = stride frequency; HR Recovery = recovery heart rate prior to subsequent walking bout; * = significant difference ($p < 0.05$); S = small; M = moderate; L = large.

All gender differences in walking performance variables between DL and AW are listed in Table 3. When HR values were compared, sex differences were evident during the DL walking condition ($F = 4.02$, $p = 0.04$, $\eta_p^2 = 0.12$). During DL walking at 1 mph women had higher HR values compared to males ($t = 2.69$, $p = 0.01$, $d = 0.6$). This was also evident at 2 mph ($t = 2.9$, $p = 0.007$, $d = -0.06$) and 3 mph ($t = 3.7$, $p < 0.001$, $d = 1.35$). No gender differences were noted during the AW conditions ($F = 0.66$, $p = 0.44$, $\eta_p^2 = 0.02$). It was also determined that no significant gender differences existed for SF during the DL ($F = 2.96$, $p = 0.06$, $\eta_p^2 = 0.09$) or AW conditions ($F = 1.03$, $p = 0.32$, $\eta_p^2 = 0.036$).

Table 3
Gender Differences in HR (bpm) Response and Stride Frequency

Variable	Females ($M \pm SD$)	Males ($M \pm SD$)	Cohen's d	Effect Size
Dry HR @ 1 mph*	106.5 ± 11.1	95.3 ± 11.7	0.98	M
Wet HR @ 1 mph	97.5 ± 9.0	88.2 ± 10.6	0.95	M
Dry HR @ 2 mph*	111.6 ± 9.9	99.7 ± 12.1	1.08	M
Wet HR @ 2 mph	110.9 ± 9.6	101.9 ± 8.3	1.00	M
Dry HR @ 3 mph*	127.5 ± 14.0	109.6 ± 12.5	1.35	L
Wet HR @ 3 mph	143.8 ± 17.2	138.6 ± 12.3	0.35	S
Dry SF @ 1 mph	185.5 ± 19.8	186.1 ± 23.3	-0.03	T
Wet SF @ 1 mph	140.7 ± 17.6	144.9 ± 16.8	-0.24	S
Dry SF @ 2 mph	255.0 ± 19.9	250.1 ± 18.5	0.26	S
Wet SF @ 2 mph	201.7 ± 20.9	199.5 ± 12.6	0.13	T
Dry SF @ 3 mph	308.1 ± 18.6	295.3 ± 10.4	0.85	M
Wet SF @ 3 mph	256.4 ± 34.3	252.2 ± 13.7	0.16	T
Dry HR Recov. After 1 mph	102.1 ± 11.2	90.9 ± 9.9		
Wet HR Recov. After 1 mph	91.5 ± 8.8	83.0 ± 12.2		
Dry HR Recov. After 2 mph	101.1 ± 13.3	93.2 ± 9.8		
Wet HR Recov. After 2 mph	93.1 ± 10.3	81.7 ± 12.9		

Note. $M \pm SD$ = mean ± standard deviation; HR = heart rate; SF = stride frequency; HR Recov. = recovery heart rate prior to subsequent walking bout. T = trivial; S = small; M = moderate; L = large; * = significant difference between males and females ($p < .05$)

Discussion

The purpose of this study was to compare DL and AW conditions to determine if AW is a viable alternative exercise modality for college-age individuals. Furthermore, we examined whether HR and SF differences existed between college-age males and females while performing DL and AW on an underwater treadmill. We had hypothesized that HR would be higher at all speeds during the AW conditions when compared to DL conditions and SF would be higher at all speeds for DL conditions when compared to AW conditions. We also hypothesized that males would have lower HR and SF values during both DL and AW conditions when compared to female values during similar conditions.

Participant Compliance

Throughout the research study, 100 percent participant compliance occurred. Additionally, no injuries of any type were recorded during the 60 (2 training sessions x 30 participants) sessions of dry-land and aquatic treadmill walking. A lack of adverse events with this study was similar to that reported by other studies completed utilizing an underwater treadmill to perform AW (Conners et al., 2014; Rife, 2008). The lack of adverse events during the study was most likely due to the moderate intensity and the short duration of exercise that was performed in both of the exercise mediums.

Dry-land and Aquatic Walking Performance Variables

To measure exercise intensity of the participants, the researchers recorded HR and SF values throughout both DL and AW sessions. Recent studies have shown that HR is directly influenced by immersion of water (Bocalini et al., 2017). Specifically, protocols having water at chest level were proven to reduce HR compared to land conditions. We hypothesized that HR values would be higher at all speeds during AW conditions when compared to similar speeds during DL conditions and SF values would be higher at all speeds during DL walking conditions when compared to AW conditions. Our results showed that this was not universally supported; therefore, the hypotheses were rejected. When AW was compared to DL walking significant differences were found for HR values at 1 mph ($p < 0.001$) and 3 mph ($p < 0.001$). The average HR for DL walking trials at 1 mph (100.9 bpm ± 12.5) was higher than the average HR for AW trials at 1 mph (92.8 bpm ± 10.8). The average HR for dry-land trials (118.6 ± 15.9) was lower than the average HR for AW trials at 3 mph (141.2 ± 14.9). There were also significant differences in stride frequencies at 1 mph ($p < 0.001$), 2 mph ($p < 0.001$), and 3 mph ($p < 0.001$). Our findings concurred with studies performed by Stevens & Morgan (2010), which indicated that HR values were lower in AW conditions due to the hydrostatic pressure of water. Increased hydrostatic pressure leads to an increase in venous return which causes an increase in stroke volume; therefore, an individual is able to exercise at a lower HR during AW. Overall findings from the current project suggested that AW had similar effects on HR compared to land walking and this occurred while providing less stress on the joints of the lower body because of the effect hydrostatic pressure of water has on the body. We also noted that each participant achieved at least moderate intensity exercise according to

ACSM guidelines (40-60% HR max) during each speed trial during both (DL & AW) walking conditions.

While HR values fluctuated between dry-land and aquatic conditions, SF values were higher at all speeds during DL conditions. These results agreed with the findings of the study by Jung, et al. (2018), which indicated that SF values were higher during dry-land conditions when compared to aquatic exercise conditions (see Table 2). This is potentially due to the added drag resistance from the water during aquatic trials. The reduction in SF while performing aquatic walking could also be due to the buoyancy of the water and the reduction in lower extremity stress experienced while performing AW (Jung et al., 2018). Aquatic walking allows for a reduction in the amount of body mass that has to be supported during aquatic walking (~50% reduction with water at waist level) and also results in reduced ground reaction forces (Barela & Duarte 2008) which can cause a difference in walking kinematics that occurs in an aqueous solution (Masumoto et al., 2007a). The lower SF values seen while walking in the aquatic exercise medium could be due to the increase vertical oscillation that occurred as a result of the buoyancy of the water. We hypothesized that the increased amount of time spent in the swing-phase of each participants' gait could be due to the buoyancy of water, which caused an increased amount of float time while performing AW. This increased floating time can result in an increased stride length for each participant and a decrease in SF during AW when compared to DL walking at the same speed.

Gender Differences in Cardiovascular Response and Stride Frequency

We hypothesized that males would have lower values in both HR and SF during the dry-land and AW trials. Results of the study indicated these hypotheses were generally not supported (see Figures 1 & 2), revealing that gender may not have impact on cardiovascular response and SF variables in healthy young adults. This assumption concurred with the findings of the research by Kaneda et al. (2011), which investigated metabolic responses of AW and compared metabolic responses of young to elderly men and women. The results indicated that there were no gender differences in this study although there were physiological differences. The study by Kaneda et al. (2011) did not utilize the underwater treadmill as in the current study. Although settings and protocols of the current study differed slightly, similar outcomes were noticed between the two studies.

DOI: https://doi.org/10.25035/ijare.12.04.13

Figure 1

Comparison of Male and Female Average HR values

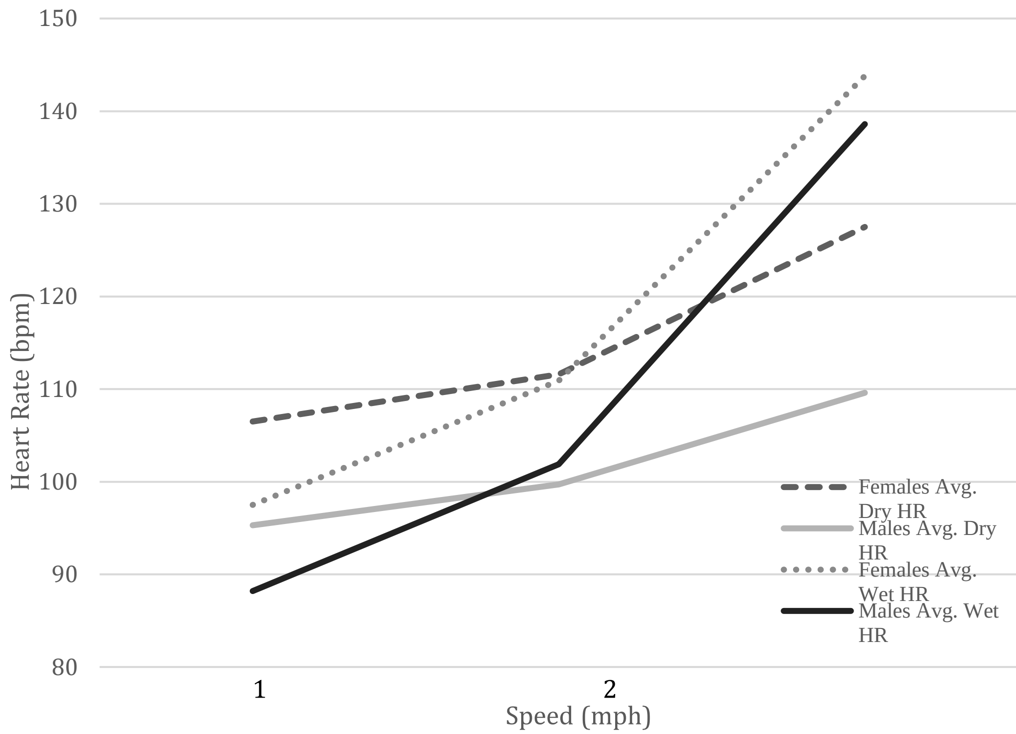
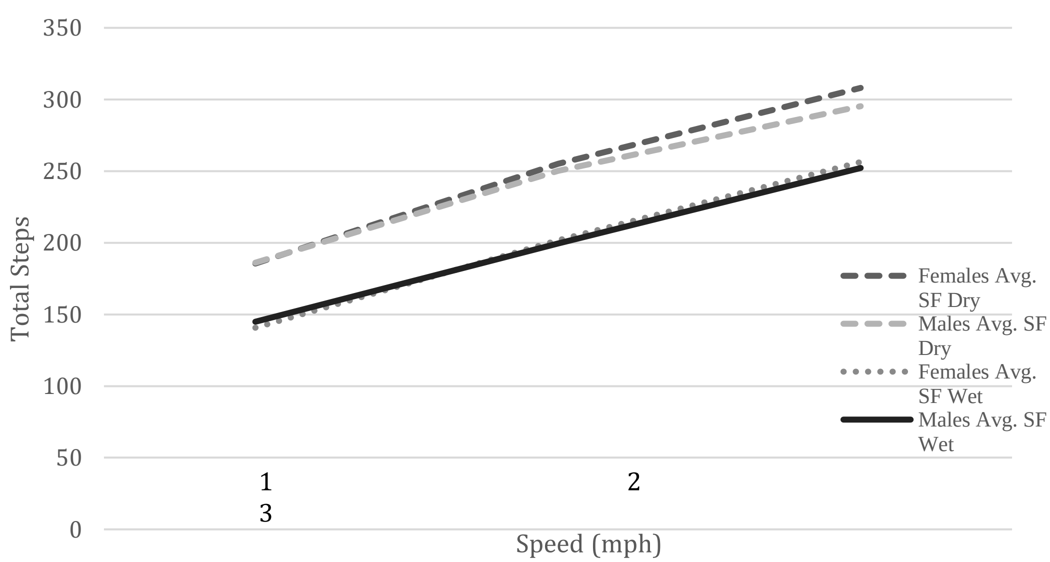


Figure 2

Comparison of Male and Female Average SF Values



The current study found significant differences between male and female HR values for DL walking conditions at 1 mph, 2 mph, and 3 mph. While female HR values were higher at all three speeds, results also showed that HR values increased as speed increased similar to the findings of the studies by Lim and Rhi (2014) and Kaneda et al. (2011). Pertaining to SF values compared between females and males, no significant differences were found at any speeds. As mentioned above the findings of Kaneda et al. (2011) suggest that there were no gender differences; however, no previous studies have made connections between gender differences and SF.

Limitations and Future Research

One limitation of the current study was the self-selected clothing choice of the participants. During the testing protocol, participants wore the same clothing in both the aquatic and dry-land walking trials. However, the difference in clothing choices among the participants may have provided small, but measurable differences in resistance while completing walking sessions in the different exercise mediums. Future studies ought to incorporate standard attire for the participants to wear during both trials.

Participants also walked barefoot during each trial which may have altered walking biomechanics to an unknown degree. Barefoot walking was chosen for this study so that shoes did not provide additional resistance while performing AW. Future research may want to consider allowing participants to wear some sort of shoe/covering to get more accurate DL walking biomechanics while performing AW. Allowing participants to wear shoes may provide stability and comfort but would also affect drag resistance. Different types of shoes could also provide more drag resistance than others, therefore increasing HR levels and skewing results.

Another potential limitation of the study was not controlling for the overall body fat percentage of each participant. A variation in the dispersion and location of each participants' body fat can potentially alter the overall amount of ground reaction forces that were reduced from walking in waist-level water. In the current study, females on average had a higher BMI, but there was not a significant difference compared to males. Also, future studies may want to identify the overall body fat percentage so this can be statistically controlled.

Another potential limitation to the current study could be the diverse background of participants. Although the study excluded athletes from participation, differences in RHR and potentially fitness level existed among the participants. Due to the fact that the sample was indicative of a typical college population, differences in hydrostatic weight may have potentially affected the level of effort individuals gave causing fluctuations in their HR values (Graef &

Kruel, 2006). Further research may want to limit or require a specific fitness level of the participant.

Conclusions

Results from this study indicated that AW increased HR values similar to those seen while walking on DL, but without the added stress to the lower extremities due to the buoyancy of the water. This is due to having half of the body immersed in water which causes the influence of gravity to be reduced, thus decreasing the participant's weight while in the water (Matsui & Onodera, 2013). The increased resistance from the water's hydrostatic pressure allowed participants to achieve at least moderate intensity exercise while simultaneously lessening the stress placed on their joints. Therefore, individuals that have medical issues or injuries can potentially use AW as an alternative form of exercise to remain physically active with less pain and less stress on their joints. Aquatic walking can potentially allow college-aged individuals to meet ACSM guidelines for PA which will also lower their risk for injuries and diseases. Exercise in an aquatic medium can be used in the development of exercise and rehabilitation prescriptions for college-aged individuals that have injuries or other issues that prevent them from exercising regularly.

References

American College of Sports Medicine. (2000). ACSM's guidelines for exercise testing and prescription. Philadelphia: Lippincott Williams & Wilkins.

Barela, A. M. F., & Duarte, M. (2008). Biomechanical characteristics of elderly individuals walking on land and in water. *Journal of Electromyography and Kinesiology*, *18*(3), 446–454. https://doi.org/10.1016/j.jelekin.2006.10.008

Barela, A. M. F., Stolf, S. F., & Duarte, M. (2006). Biomechanical characteristics of adults walking in shallow water and on land. *Journal of Electromyography and Kinesiology*, *16*(3), 250–256. https://doi.org/10.1016/j.jelekin.2005.06.013

Barnes, P.M., & Schoenborn, C.A. (2003). *Physical activity among adults: United States 2000*. Advance data from vital health statistics, no.333. Hyattsville, MD: National Center for Health Statistics.

Bocalini, D. S., Bergamin, M., Evangelista, A. L., Rica, R. L., Junior, F. L. P., Junior, A. F., & Santos, L. D. (2017). Post-exercise hypotension and heart rate variability response after water- and land-ergometry exercise in hypertensive patients. *PLOS ONE*, *12*(6), e0180216.

Cadenas-Sanchez, C., Arellano, R., Vanrenterghem, J., & López-Contreras, G. (2015). Kinematic adaptations of forward and backward walking on land and in water. *Journal of Human Kinetics*, *49*, 15–24.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Conners, R. T., Morgan, D. W., Fuller, D. K., & Caputo, J. L. (2014). Underwater treadmill training, glycemic control, and health-related fitness in adults with type 2 diabetes. *International Journal of Aquatic Research and Education*, *8*(4), 382-396. https://doi.org/10.25035/ijare.08.04.08

Fontana, H. Haupenthal, A., Ruschel C., Pizzolatti A., Cerutti P., & Roesler, H. (2011). Comparison of ground reaction forces between in-place and forward water running at two levels of immersion. *Portuguese Journal of Sport* Sciences, 11, 495-498.

Graef, F.I., & Kruel, L.F.M. (2006). Heart rate and perceived exertion at aquatic environment: Differences in relation to land environment and applications for exercise prescription: A review. *Revista Brasileira de Medicina Esporte, 12*(4), 198-204.

Greene, N. P., Greene, E. S., Carbuhn, A. F., Green, J. S., & Crouse, S. F. (2011). VO_2 prediction and cardiorespiratory responses during underwater treadmill exercise. *Research Quarterly for Exercise and Sport*, *82*(2), 264-273.

Hall, J., Grant J., Blake, D., Taylor, G., & Garbutt, G. (2004). Cardiorespiratory responses to aquatic treadmill walking in patients with rheumatoid arthritis. *Physiotherapy Research International*, *9*, 59-73.

Hamer, M., & Chida, Y. (2008). Walking and primary prevention: A meta-analysis of prospective cohort studies. *British Journal of Sports Medicine*, *42*(4), 238–243.

Hamer, M., Venuraju, S., Urbanova, L., Lahiri, A., & Steptoe, A. (2012). Physical activity, sedentary time and pericardial fat in healthy older adults. *Obesity*, *20*(10), 2113–2117.

Haupenthal, A., Fontana, H., Ruschel, C., Dos Santos, D., & Roesler, H. (2013). Ground reaction forces in shallow water running are affected by immersion level, running speed, and gender. *Journal of Science and Medicine in Sport*, *16*, 348-352.

Haupenthal, A., Ruschel, C., Hubert, M., Fontana, H., & Roesler, H. (2010). Loading forces in shallow water running at two levels of immersion. *Journal of Rehabilitation Medicine*, *42*, 664–669.

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3-13.

Jung, T., Kim Y., Lim, H., & Vrongistinos K. (2018). The influence of water depth on kinematic and spatiotemporal gait parameters during aquatic treadmill walking. *Sports Biomechanics*, *18*(3), 297-307.

Kaneda, K., Ohgi, Y., & Tanaka, C. (2011). Gender differences in metabolic responses during water walking. *International Journal of Aquatic Research and Education*, *5*(4), 421-431. https://doi.org/10.25035/ijare.05.04.08

Lim, K. I., & Rhi, S. Y. (2014). The effects of landed and aquatic treadmill walking at moderate intensity on heart rate, energy expenditure, and catecholamine. *Journal of Exercise Nutrition & Biochemistry*, *18*(2), 197–203.

Masumoto, K., Nishizaki, Y., & Hamada, A. (2013). Effect of stride frequency on metabolic costs and rating of perceived exertion during walking in water. *Gait & Posture*, *38*(2), 335–339.

Masumoto, K., Shono, T., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2007a). Age-related differences in muscle activity, stride frequency and heart rate response during walking in water. *Journal of Electromyography and Kinesiology*, *17*(5), 596–604. https://doi.org/10.1016/j.jelekin.2006.06.006

Masumoto, K., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2007b). A comparison of muscle activity and heart rate response during backward and forward walking on an underwater treadmill. *Gait & Posture*, *25*(2), 222–228.

Masumoto, K., Takasugi, S., Hotta, N., Fujishima, K., & Iwamoto, Y. (2004). Electromyographic analysis of walking in water in healthy humans. *Journal of Physiological Anthropology and Applied Human Science*, *23*(4), 119–127.

Matsui, T., & Onodera, S. (2013). Cardiovascular responses in rest, exercise, and recovery phases in water immersion. *Journal of Physical Fitness Sports Medicine*, *2*(4), 475-480.

McNarry, M. A., Wilson, R. P., Holton, M. D., Griffiths, I. W., & Mackintosh, K. A. (2017). Investigating the relationship between energy expenditure, walking speed and angle of turning in humans. *PLOS ONE*, *12*(8). https://doi.org/10.1371/journal.pone.0182333

Oeveren, B. T. van, Ruiter, C. J. de, Beek, P. J., & Dieën, J. H. van. (2017). Optimal stride frequencies in running at different speeds. *PLOS ONE*, *12*(10). https://doi.org/10.1371/journal.pone.0184273

Peacock, L., Hewitt, A., Rowe, D. A., & Sutherland, R. (2014). Stride rate and walking intensity in healthy older adults. *Journal of Aging & Physical Activity*, *22*(2), 276–283.

Rife, R. K. (2008). *Physiological Differences between Land and Water Treadmill Running* (Master's thesis). https://pdfs.semanticscholar.org/d1c4/52b8d087623ff9be7410d0c7c8512e0ab6f8.pdf?_ga=2.90086107.1794730448.1575988993-1353310708.1575988993

Roesler, H., Haupenthal, A., Schutz, G.R., & de Souza, P.V. (2006). Dynamometric analysis of the maximum force applied in aquatic human gait at 1.3 m of immersion. *Gait & Posture*, *24*, 412–417.

Schaal, C., Collins, L., & Ashley, C. (2012). Cardiorespiratory responses to underwater treadmill running versus land-based treadmill running. *International Journal of Aquatic Research and Education*, *6*(1), 35-45. https://doi.org/10.25035/ijare.06.01.06

Silvers, W. M., Rutledge, E. R., & Dolny, D. G. (2007). Peak cardiorespiratory responses during aquatic and land treadmill exercise. *Medicine & Science in Sports & Exercise*, *39*(6), 969–975.

Stevens, S., & Morgan, D. W. (2010). Underwater treadmill training in adults with incomplete spinal cord injuries. *Journal of Rehabilitation Research & Development*, *47*(7), 7-10.