

Influence of Height and BMI on Weight Bearing of Male and Female Individuals at Two Levels of Human Immersion- A Cross-Sectional Study

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Introduction

Human immersion in water is a popular therapeutic technique in physical therapy and other health care professions. Performance of functional closed-chain exercises that may otherwise be too difficult on land is made possible in water due to buoyant force which reduces loading across weight bearing joints.¹ Reduction in body weight bearing with increasing depth of water immersion is therefore used to advantage by physical therapists to attain reduction in pain, improve movement performance and induce relaxation in skeletal muscles. Several areas of application of the properties of water that have evolved in the form of hydrotherapy include rehabilitation of patients with arthritis^{2,3} treatment of patients with total hip replacement^{4,5} post-game or post-training recovery⁶ and gait re-training following total knee arthroplasty.⁷ Indeed, rehabilitation of patients recuperating in the acute phase of most orthopaedic clinical conditions can be easily performed with hydrotherapy.

Knowledge of the extent of weight bearing of immersed individuals thus becomes necessary during performance

ABSTRACT

Objective: The study determined the gender difference in body weight bearing at anterior superior iliac spine (ASIS) and xiphisternum levels of human immersion in relation to BMI and height.

Methods: Apparently healthy undergraduates (96 males; 97 females) participated in this study. Their body weights were measured on land in erect standing using water-proof weighing scale. The procedure was repeated in water while immersed at ASIS and xiphisternum. Percentage weight bearing (PWB) and body mass index (BMI) were determined from the scores obtained. Inferential analysis included two sample t-test and linear multiple regression at $p < 0.05$.

Results: The mean age of the participants was 22.4 years. The body weight and height were significantly higher ($p < 0.05$) for male than the female participants. The PWB for male participants was significantly higher ($p < 0.001$) than in the female participant at ASIS (54.8 ± 0.1 vs 47.7 ± 0.1), and at xiphisternum (31.2 ± 0.1 vs 25.5 ± 0.1) levels respectively. Male participants' PWB was directly correlated with their height ($\beta = 0.26$; $p = 0.011$) whilst the female participants' PWB had indirect correlation with BMI ($\beta = -0.38$; $p < 0.001$) at xiphisternum level.

Conclusion: Male participants experienced higher PWB than their female peers at both immersion levels in this study. The gender difference was influenced by their height and BMI at xiphisternum level only.

Key words: aquatic rehabilitation, anthropometry, gender science

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of exercises or whilst using hydro pool at rest. Several studies have been able to determine weight bearing of individuals in standing position during graded water immersion.⁸⁻¹⁰ Effective off-loading of 40% and 60% of

body weight when an individual is immersed to the levels of pubic symphysis and xiphoid respectively has been reported.¹¹ Earlier trial has also led to the derivation of formulae for calculating percentage weight bearing (PWB) for male and female adults at three levels of water immersion using age, BMI and body fat composition as determining variables.¹⁰ The authors defined PWB as a measure of body weight borne during immersion in water divided by the weight of the same individual on land and multiplied by 100. In spite of the previous documentations however, there is dearth of information on weight bearing of male and female individuals for use during graded water immersion by physiotherapists across Sub-Saharan Africa.

One major physiological difference between male and female individuals is the tissue dependent variables such as the body weight, the level of adiposity and the height.¹² Body mass index, defined as body weight (kg) divided by height squared (m^2), remains the most frequently used tools in field settings because of its simplicity and low cost.¹³ It has however been suggested that racial and ethnic differences affect the relationship between BMI and body fatness.¹³ In view of the potential effects of the anthropometric-based measurements, sex, and ethnicity on the body weight of individuals, a population-based data is therefore necessary to serve as a guide in the use of hydro pool. This study thus determined the weight bearing of apparently health male and female

individuals during immersion to the levels of anterior superior iliac spine and xiphisternum in relation to the height and BMI of the participants in Ghana.

MATERIALS AND METHODS

Participants

Apparently healthy consenting university undergraduates were invited to participate in this study using purposive sampling technique. Their eligibility depended on the following criteria: no skin rashes or open infection, no abnormal blood pressure, no history of epileptics, absence of structural deformities affecting lower and upper limbs and no intake of medication that can affect wakefulness during immersion. Female participants undergoing their menstruation at the period and those who were under 18 years of age were excluded from the study.

Instruments

The body weight of the participants was measured to the nearest 0.01kg using an industrial scale on land and in water (Figure 1). The scale operates on a water proof load cell IP67 which was converted to derive its power supply from an in-built rechargeable dry cell battery for the purpose of this study. The load cell is incorporated into a framework of rigid iron bars that are caged in a removable large steel platform (60cm x 60cm) on which the weight is placed. The measured weight is electronically transmitted into a digital indicator (5000 series

Xtreme W) placed at the pool edge through a connecting cable of about 1.8 meters long. The machine is calibrated from 0-300kg. Wooden platforms (Breath=44cm; Length=36cm; Height 15cm) were used to vary the immersion for the participants whilst the standard hospital height meter was used to measure participants' height.

Protocols

Approval for the study's protocol was obtained from both the Ethics Committees of the University of Ghana, School of Allied Health Sciences and University of Ibadan/University College Hospital. Objective assessment was performed to ascertain participants' limb length, skin condition, breathing rate and blood pressure. The format for measurement procedures were standardized on land and in water. All participants were required to dress in light swimming costumes while female participants were also provided with swimming caps to protect their hair. The costumes and caps were kept aseptic after each use to prevent cross infection. Participants' body weight and height were measured to calculate their body mass index. They prepared for the immersion session by performing the routine shower-bath and they maintained the same dresses worn during measurements on land and in water.

Measurements in hydro pool

The weighing scale was positioned in the pool after proper cleaning. Participants with researchers' assistance then entered the pool using steps and handrails. The wooden platforms were mounted on the weighing scale after which each participant was required to step on it in order to obtain the participants' specific level. The weight of the participants and the platforms were read on the digital indicator after three seconds in erect standing posture. The exact body weight of the participants were determined when they stepped off the scale by subtracting the weight of the wooden platforms from the initial measured weight. The accuracy of stepping on the platforms was ensured by the research assistant during the measurement. To obtain the percentage weight bearing (PWB), body weight scores of the participants in water were divided by their weight on land and multiplied by 100. The procedure was based on the protocol described in previous studies.⁸⁻¹⁰

Data analyses

Data generated were analyzed using the Statistical Package for Social Sciences (SPSS) version 16.0. Descriptive statistics such as mean and standard deviation were used to summarize the age, heights, BMI and percentage weight bearing whilst two sample t-test was used to compare the means of these variables on gender basis. Linear multiple regression was used to determine the correlation of

the participants' PWB with their BMI and height. Alpha level was set at $p < 0.05$ for all the significant statistical tests.

Results

One hundred and ninety-three apparently healthy undergraduates (96 males; 97 females) participated in this study. The participants' physical characteristics are presented in **Table 1**. Their age ranged from 18 to 40 years (mean = 22.4 ± 2.7 years). The mean age of the male participants was 23.1 ± 3.2 years compared to 21.3 ± 1.9 years for females. The mean weight and height of the subjects were 60.7 ± 10.4 kg and 1.6 ± 0.1 m respectively. Male participants were significantly older and had significantly higher ($p < 0.05$) body weight and height than the female participants. The mean BMI of the participants was 22.1 ± 3.3 kg/m². There was no significant difference ($p > 0.05$) in the BMI of male and female participants. Male participants had significantly higher PWB than their female counterparts at ASIS (54.8 ± 0.1 vs 47.7 ± 0.1 ; $p < 0.001$), and at xiphisternum (31.2 ± 0.1 vs 25.5 ± 0.1 ; $p < 0.001$) levels respectfully (**Table 2**). The participants' BMI and height were correlated with PWB using multiple linear regressions (**Table 3**). There was significant direct correlation between male participants' PWB and their height ($\beta = 0.26$; $p = 0.011$) whilst the female participants' PWB had significant indirect correlation with BMI ($\beta = -0.38$; $p < 0.001$) at xiphisternum level. However, there was no

significant correlation between PWB and all the selected variables for male and female participants at ASIS.

Discussion

The results of this study indicate that male participants had significantly higher percentage weight bearing (PWB) than their male counterparts at both immersion levels. This finding is in tandem with the results of the previous studies in which male subjects bore more weight at rest or during slow paced walking on account of differences in tissue composition and somatotype.⁸⁻¹⁰ Specifically, size-dependent variables such as fat composition, height and lean body mass have been identified as the main determinants of the physiological variation between both sexes which tend to predispose male individual to greater body than their female peers.^{9,12}

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Figure 1: Water-proof weighing scale, the wooden platforms and the digital monitor.



Table-1: Physical characteristics of the participants.

| Characteristics | Male n=96 (Mean±SD) | Female n=97 (Mean±SD) | All participants N=193 (Mean±SD) | MD (95% CI) | p-value |
|--------------------------|---------------------------|-----------------------------|---|-----------------------|---------|
| Weight (kg) | 62.8±10.7 | 58.6±9.7 | 60.7±10.4 | 4.2 (1.31 to 7.11) | 0.005* |
| Height (m) | 1.7±0.1 | 1.6±0.1 | 1.6±0.1 | 0.1 (0.06 to 0.10) | <0.001* |
| Age (yrs) | 23.1±3.2 | 21.3±1.9 | 22.4±2.7 | 1.3 (0.56 to 2.09) | 0.001* |
| BMI (kg/m ²) | 21.7±3.3 | 21.3±1.9 | 22.1±3.3 | -0.8 (-1.72 to -0.17) | 0.109 |

* = significant at p<0.05; MD = Mean difference

Table-2: Percentage weight bearing for male and female participants at anterior superior iliac spine and xiphisternum levels

| Variable | Male (n=96) | Female (n=97) | All participants (N=193) | MD (95% CI) | p-value |
|--------------|-------------|---------------|-----------------------------|------------------|---------|
| ASIS | 54.8±4.8 | 49.7±5.8 | 52.3±5.8 | 0.1(0.03 - 0.06) | <0.001* |
| Xiphisternum | 31.2±5.5 | 25.7±6.1 | 28.4±6.2 | 0.1(0.04 - 0.07) | <0.001* |

Legend: * = significant at p<0.05

Key: PWB=Percentage weight bearing; MD= Mean difference

Table-3: Correlation between percentage weight bearing and participants' anthropometric variables

| Variables | Height | | BMI | |
|----------------------------|---------|---------|---------|---------|
| | β | p-value | β | p-value |
| PWB at ASIS | | | | |
| Male | 0.12 | -0.268 | -0.08 | 0.457 |
| Female | -0.11 | 0.266 | -0.15 | 0.158 |
| PWB at xiphisternum | | | | |
| Male | 0.26 | 0.011* | -0.10 | 0.342 |
| Female | -0.11 | 0.271 | -0.38 | 0.001* |

* =Significant at p<0.05

Legend: PWB= Percentage weight bearing; ASIS= Anterior superior iliac spine

physiological variation between both sexes which tend to predispose male individual to greater body than their female peers.^{9,12}

Conclusion:

Male participants had greater PWB than their female participants at anterior superior iliac spine and xiphisternum levels of immersion and the PWB scores were only influenced by their height and BMI at xiphisternum levels of immersion. These findings should therefore serve as basis for immersion during rehabilitation or whilst using hydro pool for recreation.

Conflicts of interest

None identified and/or declared.

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