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The Effect of Fluid Consumption and Exercise on Segmental Bioelectrical Impedance

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Abstract: Bioelectrical impedance analysis (BIA) is a simple, noninvasive technique to determine body composition. The fundamental principle of determining body composition via bioelectrical impedance is to determine the resistance to, or conductance of, a low voltage current applied to biological tissue. Bioelectrical impedance analysis is well correlated to total body water. Bioelectrical impedance is sensitive to fluid shifts namely changes in blood flow, changes in electrolyte concentration, and changes in hydration status and consequently bioelectrical impedance has been used as a tool to measure such changes. Thirty college-aged students, 18-25 years old, 18 men and 12 women were subjects for this study. Bioelectrical impedance was determined with the Tanita BC-418 at two time points. Subjects were instructed to drink 490ml of water then exercised on the treadmill for 30mins. Our results show a significant decrease in resistance in both the sum of the upper limbs and the sum of the lower limbs indicating a fluid shift that is related to the fluid consumed by the subjects, but independent of tonicity.

Key Words: Body composition, Hydration status, Fitness

1 Introduction

Body composition, expressed as body fat percentage, has strong associations with relative risk of serious but largely preventable chronic disease [1-3]. Bioelectrical impedance analysis (BIA) is a simple, noninvasive technique to determine body composition. Use of the bioelectrical impedance equipment requires little training, it is inexpensive to operate, and its portability has made its use widespread in clinical, fitness, health and research settings [4-6]. Bioelectrical impedance is influenced by ethnicity, menstrual status, ambient temperature, skin temperature, and hydration status, therefore bioelectrical impedance may not be appropriate in studies with diverse populations [7-9]. Bioelectrical impedance can be used in healthy subjects (those without fluid and electrolyte abnormalities) to accurately determine fat mass, fat-free mass, and total body water (TBW) when applying the appropriate equation(s) [10-12].

The fundamental principle of determining body composition via bioelectrical impedance is to determine the resistance to, or conductance of, a low voltage current applied to biological tissue [13, 14]. Both intracellular and extracellular fluids act as electrical conductors. The penetration of this current into the body's fluid compartments is frequency dependent, with the higher frequencies (>50 kHz) penetrating both the intracellular and extracellular compartments [13]. Differences in volume and electrolyte content affect conductance and resistance of the applied current (resistance is the inverse to conductivity). The bioelectrical impedance method utilizes the greater conductivity of fat free mass and the greater resistance of the fat mass in the determination of body composition [15, 16].

Bioelectrical impedance analysis is well correlated to total body water [17]. Total body water (TBW) remains relatively stable contributing to about 60% of an individual's body weight (45 liters for a 75kg person). Total body water measurements obtained from bioelectrical impedance and isotope dilution (the gold standard in TBW determination) in controlled experiments are well correlated [18]. Bioelectrical impedance is sensitive to fluid shifts namely changes in blood flow, changes in electrolyte concentration, and changes in hydration status and consequently bioelectrical impedance has been used as a tool to measure such changes [19]. Small perturbations from dehydration to overdrinking can temporarily influence TBW. It is therefore possible to detect these changes in TBW with bioelectrical impedance. It is logical to conclude that segmental bioelectrical impedance can be used to detect changes in segmental fluid distribution post exercise and post fluid consumption [20].

It is important to further evaluate bioelectrical impedance as a tool to evaluate fluid shifts in exercising athletes. Scrutiny of hydration guidelines/recommendations is warranted. The ability to track changes in fluid compartments with drinking and in response to muscle activity associated with exercise would be useful in improving fitness. Furthermore, the use of segmental bioelectrical impedance can clarify the nature and magnitude of fluid shifts to different regions of the body. The purpose of this work is to evaluate changes in segmental bioelectrical impedance in euhydrated individuals following the consumption of water and moderate exercise.

2 Methods

2.1 Experimental Approach to the Problem

We examined changes in segmental bioelectrical impedance in euhydrated individuals following the consumption of 490ml of water and 30 minutes of moderate exercise. Thirty college-aged students, 18-25 years old, 18 men and 12 women were subjects for this study. All subjects were at the time members of SUNY Fredonia athletic teams. The research protocol was approved for human subjects by the SUNY Fredonia Human Subject Review Board. Subjects were deemed "apparently healthy" when it was determined that they were free of signs and symptoms of cardiovascular and pulmonary disease and met the criteria for the American College of Sports Medicine (ACSM) low risk stratification for coronary artery disease [21]. Additional exclusionary criteria included: recent lower limb skeletal muscle injuries, the use of medication that could influence total body water, electrolyte composition and/or kidney dysfunction. Lastly, a urine specific gravity greater than 1.025 at the beginning of the data collection session would exclude the subject from further data collection that day and require a rescheduling of data collection to another day.

All subjects reported to the lab between 11am and 1pm EST on testing days. All subjects were instructed to refrain from eating for at least 4 hours before arriving at the lab and to not engage in vigorous exercise within 12 hours of testing. No female subjects were tested during their menstrual period. Bioelectrical impedance was determined with a Tanita BC-418 Segmental Body Composition Analyzer. The analyzer uses employs a consistent high frequency current (50kHz, 500μA) across 8 electrodes. The supply of current from the electrodes is to the tips of the toes of both feet with the voltage measured at the heels of both feet, and to the fingertips of both hands with the voltage measured at the thenar side of both hands. The current flows into the upper limbs or lower limbs, depending on the body part(s) to be measured. The data output of interest in our study includes resistance expressed in Ohms for each arm and each leg.

Upon arriving at the lab subjects were required to provide a urine sample to determine urine specific gravity and hydration status. Next, initial bioelectrical impedance was determined with the Tanita BC-418 following the guidelines outlined by the manufacturer. The subject was then instructed to drink in its entirety a commercially available bottle of water (490ml). Subjects then exercised on the treadmill. The first 15 minutes on the treadmill consisted of subjects walking at 3.3 mph at a 1.5% incline. At the 15 minute mark the speed was increased to 3.5 mph at a 1.5% incline. At the completion of 30 minutes subjects were again asked to provide a urine sample and their bioelectrical impedance was analyzed.

Statistical techniques

The resistance values were summed for the upper and lower limbs for each of the 30 subjects. Data were analyzed using a Paired T-test comparing the resistance values at the initial and post-exercise time points. A significance level of 0.05 was used for comparison.

There is a significant difference in resistance for the upper limb sum at the initial and post-exercise time points ($t = 2.40$, $df = 29$, $P = 0.023$). The mean resistance for the initial time point is 650.67 (standard error = 21.35) and for post-exercise is 641.13 (standard error = 20.63). There is a significant difference in resistance for the lower limb sum at the initial and post-exercise time points ($t = 6.21$, $df = 29$, $P < 0.0005$). The mean resistance for the initial time point is 522.47 (standard error = 16.51) and for post-exercise is 506.70 (standard error = 15.15) Table 1 & Figure 1.

Discussion

Previous work has examined the influence of consuming various types of fluids, including water, saline, electrolyte replacement, and carbohydrate replenishment drinks on bioelectrical impedance [22-24]. The expected result of the consumption of fluids (hypertonic solutions) would be a decrease in resistance because of more fluid being available to conduct the applied current. When water (or other hypotonic solution) is considered however, it should result in an increase in resistance because the decrease in relative electrolyte concentration would resist current independent of the temporary volume increase. This increase in resistance with water intake was seen in work done by Gomez et al. and Saunders et al [22, 25].

Table 1. Paired T-test results comparing sum of upper and lower limb resistance at initial and post-exercise time points.

Limb Sum	Time	Mean	N	Std. Deviation	Std. Error Mean	t	df	P
Upper	Initial	650.67	30	116.94	21.35	2.40	29	0.023
	Post-Exercise	641.13	30	112.97	20.63			
Lower	Initial	522.47	30	90.40	16.51	6.21	29	<0.0005
	Post-Exercise	506.70	30	82.98	15.15			

However, our results show significant decrease in resistance in both the sum of the upper limbs and the sum of the lower limbs indicating a fluid shift that is related to the fluid consumed (water) by the subjects, but independent of tonicity.

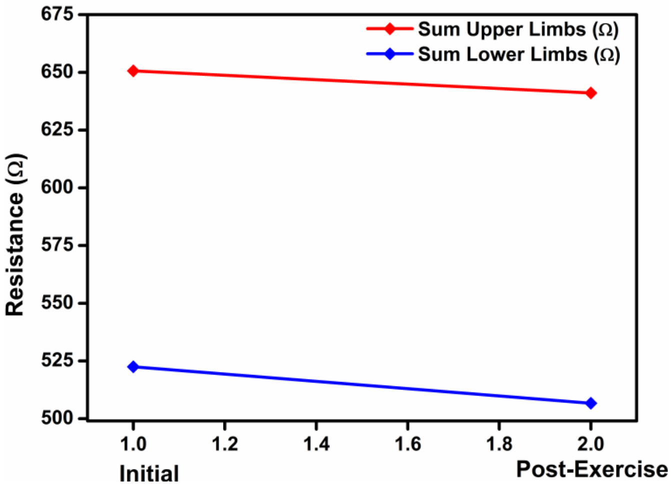

Figure 1. The line diagram shows Initial and Post-Exercise resistance in Ohms for the sum of the upper limbs and the sum of the lower limbs.

Whole body aerobic exercise such as treadmill walking elicits changes in blood flow directly related to muscle recruitment and the intensity of the activity [26]. The increase in muscle blood flow is mediated through local and central vasodilators. The increase in active blood flow to muscle could be also augmented by the influence of gravity [27]. Lower limb muscle would naturally be expected to experience a greater fluid shift as a result of both activity and gravity during upright treadmill exercise. Our results of the greater significant decrease in resistance for the sum of the lower limbs compared with the upper limbs, supports both an intensity and gravity dependent fluid shift.

It is important to note the subjects in our study were considered euhydrated at the beginning of data collection. It could be expected that the subjects would not have voluntarily consumed any water prior to engaging in a bout of exercise. Therefore, the 490 ml water (a commercially available serving size) consumed as part of the study represents fluid not needed to replace a fluid deficit but an excess of fluid not needed. Palma et al. reported the maximal absorption rate of the human GI system to be 600ml/hr, with higher fluid consumption amounts resulting in gastric upset [28]. In an observational study Noakes et al. reported voluntary fluid consumption rates of athletes to be between 400ml to 800ml/hr [29]. In our study, euhydrated subjects consumed 490 ml prior to exercise. It is possible that esophageal and gastric distention from the fluid consumed elicited a physiological cascade of events that augmented the shift of fluid to areas where it is easier to push fluid into, namely with gravity (augmented by localized vasodilation) and active skeletal muscle.

Exercise performance was not evaluated in this study. Previous studies performed in our lab have demonstrated that involuntarily consumption of water in a euhydrated condition state impairs exercise performance [30, 31]. Although the exact mechanisms behind this impairment have not been elucidated, it is possible that over drinking water leads to excessive fluid shifts to the lower limbs. This fluid shift could potentially lead to leg edema which could alter the biomechanics of running thus impairing performance.

Conclusions

Our study is unique because it examined changes in segmental bioelectrical impedance in response to both fluid consumption and exercise. both the bout of exercise and fluid volume consumed are representative of real world behaviors of people looking to improve fitness. Future hydration research would benefit from more applicable protocols in order to formulate guidelines for people to follow.

Subsequent studies in this area of research can examine differing exercise modes, different types of drinks or exercise performance measures.

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