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Serum osmolarity and haematocrit do not modify the association between the impedance index (Ht^2/Z) and total body water in the very old: The Newcastle 85+ Study

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ABSTRACT

Purpose of the research: Bioelectrical impedance is a non-invasive technique for the assessment of body composition; however, information on its accuracy in the very old (80 + years) is limited. We investigated whether the association between the impedance index and total body water (TBW) was modified by hydration status as assessed by haematocrit and serum osmolarity.
Materials and methods: This was a cross-sectional analysis of baseline data from the Newcastle 85 + Cohort Study. Anthropometric measurements [weight, height (Ht)] were taken and body mass index (BMI) calculated. Leg-to-leg bioimpedance was used to measure the impedance value (Z) and to estimate fat mass, fat free mass and TBW. The impedance index (Ht2/Z) was calculated. Blood haematocrit, haemoglobin, glucose, sodium, potassium, urea and creatinine concentrations were measured. Serum osmolarity was calculated using a validated prediction equation.
Principal results: 677 men and women aged 85 years were included. The average BMI of the population was 24.3 ± 4.2 kg/m2 and the prevalence of overweight and obesity was 32.6% and 9.5%, respectively. The impedance index was significantly associated with TBW in both men (n = 274, r = 0.76, $p < 0.001$) and women (n = 403, r = 0.96, $p < 0.001$); in regression models, the impedance index remained associated with TBW after adjustment for height, weight and gender, and further adjustment for serum osmolarity and haematocrit. The impedance index values increased with BMI and the relationship was not modified by hydration status in women (p = 0.69) and only marginally in men (p = 0.02).
Major conclusions: The association between the impedance index and TBW was not modified by hydration status, which may support the utilisation of leg-to-leg bioimpedance for the assessment of body composition in the very old.

1. Introduction

The enhanced longevity of the human race is exemplified by the rising number of people aged 80 years or over (very old) (Oeppen & Vaupel, 2002). There are currently three million people aged more than 80 years in the UK and this is projected to almost double by 2030, reaching eight million by 2050 (Cracknell, 2010). In 2009, 102 million people worldwide were aged 80+ and the number is predicted to almost quadruple to 395 million by 2050 (United Nations, 2009).

Accurate assessment of nutritional status in the very old is fundamental to address the lack of clear definition of nutritional requirements in this age group as well as the association between nutritional status with health, disability and survival (Loreck, Chimakurthi, & Steinle, 2012). However, nutritional assessment in older people is limited by the predictive inaccuracy of established anthropometric measurements such as BMI, waist circumference (WC), and waist–hip ratio (WHR). In fact, these measurements become almost clinically meaningless in the very old (Reis et al.,

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2009; van Vliet, Oleksik, van Heemst, de Craen, & Westendorp, 2010) as many diagnostic features of anthropometry are masked by an increase in the central accumulation of fat and a decrease in appendicular FM with age (Enzi et al., 1986; Kyle et al., 2001). Therefore, the attention of nutritionists and geriatricians has shifted toward more detailed measurement of body composition to evaluate the association of adiposity and/or lean body mass with risk of disability and mortality (Woodrow, 2009).

The optimal mode of assessment of body composition in older subjects has to take into account several factors including portability of equipment, non-invasiveness and precision (Siervo & Jebb, 2010). The leg-to-leg bioelectrical impedance (bioimpedance analysis (BIA)) fulfills all these criteria and therefore could represent a valuable method for assessment of body composition the very old (Xie, Kolthoff, Barenholt, & Nielsen, 1999). The theoretical principle of BIA is based on the resistance offered by body tissues to the flow of a small electric current, which strongly correlates with the degree of tissue hydration (NIH Statement, 1996). Impedance (Z) is a direct measure of tissue conductivity and the stature-adjusted impedance index (Ht^2/Z) is utilized in predictive algorithms for the determination of body composition based on a robust association with TBW (NIH Statement, 1996). FM and FFM can then be derived based on the assumption of a constant hydration of FFM (TBW/FFM = ~0.73) (Wang et al., 1999).

The impedance index is the primary predictor of TBW in BIA-derived predictive algorithms and its accuracy is dependent largely on fluid volume and ionic solute concentrations (NIH Statement, 1996). Therefore, in theory, changes in whole-body hydration status may affect TBW measurements and consequently have an impact on the accuracy of FM and FFM measurements. Serum osmolarity is a biomarker of hydration status as it is directly related to the concentrations of osmotically active solutes impermeable to cell membranes (sodium (Na), glucose, potassium (K), and urea) (Armstrong, 2005). Changes in haematocrit may result from intravascular dehydration usually associated with diarrhea, third space fluid loss (effusions or edema) or diuretic use (Armstrong, 2005).

Several studies have indicated minimal changes in the hydration of FFM with aging (Schoeller, 1989; Wang et al., 1999). However, because of widespread use of diuretics and self-imposed restrictions in fluid intake, the very old may be at greater risk of dehydration (Hooper et al., 2014) and it is not currently known whether changes in fluid volumes and shifts in extracellular/intracellular water distribution affect performance of the BIA in this age group. Here, we assessed whether objective measures of hydration (i.e. serum osmolarity and haematocrit concentration) modified the association between the impedance index (Ht^2/Z) and TBW using baseline data from the Newcastle 85+ Study.

2. Materials and methods

2.1. Participants and study protocol

The protocol and baseline findings for the Newcastle 85+ Study have been described in detail elsewhere (Collerton et al., 2007). In short, the Newcastle 85+ Study is a population-based observational study which recruited people born in 1921, who were aged 85 in the year the study commenced (2006) and who were registered with a participating general practice in the Newcastle and North Tyneside area of the UK. Individuals in institutional care were also included. The study was approved by the Newcastle & North Tyneside Local Research Ethics Committee. Where individuals lacked the capacity to give informed consent, consultee approval was sought in accordance with the UK Mental Capacity Act 2005.

Recruitment and baseline assessment took place over a 17-month period in 2006–2007. A multidimensional health assessment (MDHA) – comprising questionnaires (including socio-economic status (income, level of education) and lifestyle), measurements and function tests (including anthropometry, BIA), and a fasting blood sample – was carried out by a trained research nurse at the participant's usual place of residence. General practice medical records were reviewed to obtain information about clinical diagnoses and prescribed medications.

Of the 854 individuals consenting to a baseline MDHA, 778 agreed to fasting blood sampling. For the present analyses, data from 677 participants with complete anthropometric, BIA and clinical biochemistry data were included.

2.2. Measurements

2.2.1. Anthropometry

Body weight was measured using a digital scale, with the participant wearing light clothes, and approximated to the nearest 0.1 kg. In view of the well-recognized difficulties in measuring height in very old people, height was estimated from demi-span. Right arm demi-span was measured to the nearest 0.1 cm; final data were the average of two measurements. Height was calculated as: [1.35 × demi-span + 60.1] for women and [1.40 × demi-span + 57.8] for men (Martin-Ruiz et al., 2011). BMI was calculated as body weight divided by squared height in meters and categorized as: underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2) and obese (≥30.0 kg/m^2).

2.2.2. Leg-to-leg bioelectrical impedance

Measurements were conducted using the Tanita-305 body-fat analyzer (Tanita Corp., Tokyo, Japan). Participants were measured standing erect with bare feet placed on the metal sole plates. The impedance value (Z) was measured and the impedance index was calculated (Ht^2/Z). TBW, FM and FFM were estimated using the inbuilt prediction equations of the bioimpedance device.

2.2.3. Clinical biochemistry

After an overnight fast, 40 ml blood was drawn from the antecubital vein between 7:00 and 10:30 am. Full blood count, electrolytes (sodium, Na^+; potassium, K^+), urea, creatinine and glucose were measured at the Department of Clinical Biochemistry at Newcastle Royal Victoria Infirmary. The modification of diet in renal disease formula (MDRD) was used to estimate glomerular filtration rate (eGFR) (Manjunath, Sarnak, & Levey, 2001). Participants were classified as having severe renal impairment if eGFR was lower than 30 ml/min/1.73 m^2 (Levey et al., 2005).

2.2.4. Serum osmolarity

The equation for serum osmolarity (mOsm/L) developed by Khajuria and Krahn (2005) was used: 1.86 × (Na + K) + 1.15 × glu-glucose + urea + 14, where all components were measured in mmol/L. The equation has been validated in 172 frail older people with and without diabetes (age: 85.8 ± 7.9 years) and was best able to predict serum osmolality compared with 35 other predictive equations (Siervo, et al., 2014). Participants were categorized as being normally hydrated (serum osmolality <295 mOsm/L; euhydration), having impending dehydration (serum osmolality 295–300 mOsm/L; pre-dehydration), or dehydrated (>300 mOsm/L) (Thomas et al., 2008).

2.2.5. Data analysis

Data are described as mean ± s.d. (continuous variables) and percentage (categorical variables). Q–Q plots and the Shapiro–Wilk test were used to test for normality. Variables were normalized before