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BIOELECTRICAL IMPEDANCE ANALYSIS IN ESTIMATION OF BODY COMPOSITION

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1. INTRODUCTION

Human body composition especially the content of fat tissue and its distribution has been extensively measured in children, adolescents, adults or elderly subjects. Body composition information, including percentage of body fat (%BF) is widely used to evaluate growth and nutrition in children and nutritional status in various disease conditions such as AIDS, Crohn disease, renal and various other diseases.[1, 2, 3, 4]

With the recent interest in personal health especially in nutritional status and fitness, a variety of non-invasive methods have been applied to assess body composition. These methods are different in their sophistication, accuracy, feasibility, cost and availability. Most of these are based on binary model (fat and fat-free mass).[1] Technologies that are available to measure body composition varies such as the underwater weighing method, which has been used as a traditional standard, skinfold-thickness measurements, bioelectrical impedance analysis and ultrasound method which have been widely used in field and clinical settings.[3, 5, 6]

Several bioelectrical impedance analysers are available commercially including hand-held, stand on and tetra-polar devices. The bioelectrical impedance analysis (BIA) method has been widely used in clinics, in sports medicine and in weight reduction programs. [7 , 8 , 9]

This technology review was requested by the Technical Working Group for Research, Family Health Development Division, Ministry of Health Malaysia.

2. OBJECTIVES

To assess the safety, effectiveness and cost-effectiveness of bioelectrical impedance analysis with regards to the estimation of body composition.

3. TECHNICAL FEATURES

Bioelectrical Impedance was first documented in 1880 (Kalvin) as a potentially, safe and convenient as well as accurate technique to measure conductivity in the body. This technique has recently become widely available. It is a commonly used method for determining body composition, since it is non-invasive, inexpensive and portable equipment. The methods is based on measuring electrical signals as they pass through the fat, lean mass and water in the body.

Thus electrical resistance and reactance together with body weight and height can estimate body composition. [7, 8]

The bioelectrical impedance analysis technique is a two-compartment model based on the principle that an electrical current, flows more rapidly through tissues with higher water and electrolyte content, than through tissue which are less hydrated. Due to the greater electrolyte content of free fat mass, it offers less resistance to electric current compared to fat tissue. Bioelectrical impedance analysis measures the impedance or opposition to the flow of an electric current through the body fluids contained mainly in the lean and fat tissue. [9]

Impedance is thus proportional to body water volume (TBW). It is based on the electrical principle that the volume of the conductor can be determined by measuring its length and impedance, such that $V=L/R^2$ whereby the V= volume, R=resistance, and L=conductor length. By sending an electrical current through the body, electrons flow through tissues that contain water and electrolytes. Electrical conductivity of the fat-free tissue mass is far greater than that of fat. In practice, a small constant current, typically 800 µA at a fixed frequency, usually 50 kHz, is passed between electrodes and the voltage drop between the electrodes provides a measure of impedance. [10]

Prediction equations, previously generated by correlating impedance measures against an independent estimate of TBW, may be used subsequently to convert measured impedance to a corresponding estimate of TBW. Lean body mass is then calculated from this estimate using an assumed hydration fraction for lean tissue. Fat mass is then calculated by subtracting free fat mass from total body mass. [11]

Methods of bioelectrical impedance analysis

Single frequency BIA (SF-BIA) generally at 50 kHz is passed between surface electrodes placed on hand and foot. Some BIA instruments use other locations such as foot-to-foot or hand-to-hand electrodes. SF-BIA permits estimation of fat-free mass and TBW. The result is based on empirical equations. The Multi-Frequency-BIA (MF-BIA) uses multiple frequencies such as 0, 1, 5, 50, 100, 200 or 500 kHz to evaluate the free fat mass (FFM) and total body water volume. The classical (whole body) BIA method or tetra polar devices measures impedance from foot to hand (H-F BIA). This technique is performed with the subjects resting in a supine position, and four adhesive skin electrodes were positioned on the dorsal surfaces of right hand and foot. Two were placed on the right wrist and hand and another two were placed on the right ankle and foot, the distal metacarpal-phalangeal and metatarsal-phalangeal, respectively. The distal electrodes (hand and foot) are used to introduce the current, whereas the proximal electrodes (wrist and ankle) are used to sense current. Body density was calculated using specific prediction equation. [12]

More recently, impedance analyzers were being developed that measure segmental impedance from lower body (bipolar foot to foot technique) or upper body (bipolar hand to hand technique)

only. These techniques use built-in software to assess body composition. The hand-to-hand bioelectrical impedance analysis (H-H BIA) technique is performed with the subjects held the device in both hands and straightened both arms forward. With individual data (age, height and weight) as input, the fat-free mass (FFM) based on its own prediction equation and percentage of body fat were calculated. [7] Figure 1 shows examples of the hand to hand or hand- held bioelectrical impedance devices.

Figure 1: Two examples of hand-to-hand bioelectrical impedance devices, HBF 306 and Quantum II.

4. METHODOLOGY

4.1 SEARCH METHODS

The electronic databases searched included Pubmed, OVID, Proquest, Cochrane library, EBM Reviews for controlled trials, HTA websites, and general databases such as Google and Yahoo. The key words used for the search were, “body composition” OR “body fat analysis” AND “bioimpedance” OR “bioelectrical impedance” OR “hand-held bioimpedance” OR “hand-held bioelectrical impedance”, AND “cost effectiveness” OR “cost analysis” AND “side-effects” OR safety OR safe, which are either used singly or in various combination.

4.2 SELECTION OF STUDIES

There was no limit in the search. Literature of any language was included. A critical appraisal of all relevant literature was performed and the evidence was graded according to the modified Catalonian Agency of Health Technology Assessment (CAHTA) scale.

5. RESULTS AND DISCUSSION

5.1 SAFETY

Some studies did mention that this test is non invasive, safe and emits no radiation to the subjects.[13,14,15] However none of the retrieved evidence discussed the safety aspect of this technology.

5.2 EFFECTIVENESS

Based on the evidences reviewed, bioelectrical impedance analysis was a commonly used technology for determining body composition. There were seven studies which compared bioelectrical impedance analysis (BIA) and other gold standard methods such as dual energy x-ray absorptiometry (DEXA), under water weighing (UW) and air displacement plethysmography (ADP). These studies reported the accuracy and reliability of bioelectrical impedance in both adults and children. However some of these studies only involved small sample size. [2, 4, 5, 6, 8, 9 level 5, 11 level 8]

Two studies by Sun G et al. and Nichols et al. reported good agreement between BIA and dual energy x-ray absorptiometry (which was used as the 'gold standard') in assessment of body composition. [4, 11 level 8] However two other studies by Eisenmann et al. and Elberg et al. showed poor correlation of body composition measurement by bioelectrical impedance analysis compared to dual energy x-ray absorptiometry. [5, 9 level 5]

Three studies reported that BIA underestimated fat body mass. Study by Bolanowski et al. showed that bioelectrical impedance did underestimate fat body mass and percentage of fat in subjects.[2] Study by Gartner et al. showed that hand-held bioelectrical impedance analysers did underestimate fat body mass and percentage of fat in subjects compared to air displacement plethysmography (ADP).[8 level 8] Studies by Eisenmann et al. and Sun G et al. reported that bioelectrical impedance analysis underestimated percentage of body fat in overweight or obese subjects but overestimated percentage of body fat in lean subjects. [4, 5 level 8]

Study by Gartner et al. showed that the usage of bioelectrical instruments could not be generalized to different ethnic groups and separate equations should be developed for estimation of body composition in different ethnic groups. [8]

Demura S et al. in their study showed good correlation between hand-held bioelectrical impedance analysers and underwater weighing (which was used as the gold standard) in estimating body composition. However this study did reported that the measurement of percentage body fat by hand-held bioelectrical impedance analysers was affected by change in the posture of the subject. [6]

A study by Nichols et al. which compared the whole body BIA and hand-to-hand BIA to DEXA method reported that the whole body BIA, provides more accurate and stable estimates of percentage body fat compared to hand-to- hand BIA. [11 level 8]

5.3 COST-EFFECTIVENESS

There was no retrievable evidence on evaluation of the cost–effectiveness of using this technology. However from various studies, discussions by the authors commented that bioelectrical impedance analysis was relatively inexpensive technique compared to DEXA or air displacement plethysmography, especially the hand held bioelectrical impedance analysers. [2, 11, 15] The price of the handheld bioelectrical impedance device was reported to be in the range of USD 30 to 60.

6. CONCLUSION

Evidences did show that BIA method tend to underestimate the percentage of body fat especially in overweight and obese individuals. Hence, the validity of this method was at stake. Most of the studies used classical (whole body) BIA method or tetra-polar devices which measured impedance from foot to hand and only a few of the studies used hand-held method. The studies did report that the whole body BIA method was more accurate in estimating percentage of body fat compared to hand-held BIA. It was also reported that the measurement of body fat by hand-held BIA was affected by the change in the posture of the subject, during the measurement process.

7. RECOMMENDATION

Based on the findings of the above review, bioelectrical impedance analysis is not recommended as it underestimates the percentage of body fat especially in the overweight and obese individual. In addition, there was insufficient evidence to support the effectiveness of hand-held bioelectrical impedance analysis in estimation of body composition.

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9. APPENDICES

9.1. Appendix I- Levels of evidence scale

Level	Strength of evidence	Study design
1	Good	Meta-analysis of RCT, Systematic review
2	Good	Large sample RCT
3	Good to fair	Small sample RCT
4		Non-randomized controlled prospective trial
5	Fair	Non-randomized controlled prospective trial with historical control
6	Fair	Cohort studies
7	Fair	Case-control studies
8	Poor	Non-controlled clinical series, descriptive studies multi-centre
9	Poor	Expert committees, consensus, case reports, anecdotes

SOURCE: ADAPTED FROM CATALONIAN AGENCY FOR HEALTH TECHNOLOGY ASSESSMENT (CAHTA), SPAIN