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# Flat Magnetic Stimulation as A New Frontier Technology for Stimulating Body Metabolism and Promoting A Healthy Lifestyle

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**Abtract**

**Background:** In humans, it is possible to evaluate energy expenditure in direct and indirect ways. These allow to obtain two important values called the Resting Metabolic Rate (RMR) and the Basal Metabolic Rate (BMR). The estimation of body composition is often conducted with Indirect Calorimetry (IC), and the Bioelectrical Impedance Analysis (BIA) or the Bioelectrical Impedance Vector Analysis (BIVA). In this study, we propose an innovative use of electromagnetic waves to stimulate metabolism and improve the patient's general health condition.

**Methods:** 10 women between 32 and 56 years old and with a BMI ranging from 18.4 kg/m2 to 25.6 kg/m2 and a mean height (H) of 162.0 ± 4.8 cm were enrolled. Patients were treated with electromagnetic wave fields for 4 weeks. Then, after 1 week of follow-up, functional measurements with BIA 101/BIVA Pro and Fitmate were observed.

**Results:** R/H decreases when T0 and T2 measurements are compared indicating better body hydration. On the contrary, Xc/H registered a slight increase and so a softer tissue. The PhA value raise was directly proportional to a positive trend change in the quality of the skeletal muscle mass as well as the intracellular/extracellular water ratio. RMR had also an improvement.

**Conclusion:** Study results showed that the innovative strategy we proposed led without discomfort or side effects to a significant improvement in RMR and bioelectrical parameters regardless of the patient's BMI. Thus, the devices we used both for assessment and treatment represent valuable and effective supports that could be widely employed in the nutrition medicine field.

**Keywords:** flat magnetic stimulation; body metabolism; healthy lifestyle; Indirect Calorimetry (IC); Bioelectrical Impedance Analysis (BIA); Bioelectrical Impedance Vector Analysis (BIVA); Body hydration; Nutritiona; Mellitus; Aerobic; Bioelectrical; Gynaecology; Ellipses

## Introduction

In humans, metabolism is the rate of energy expenditure. A consistent amount of this energy ranging 50-75%, is essential for the development and maintenance of basic organic functions while at rest. It is possible to evaluate energy expenditure in direct and indirect ways. These allow to obtain two important values called the Resting Metabolic Rate (RMR) [1-3], which indicates the amount of energy that the body needs to function while doing low-effort daily activities or resting (for example eating/chewing, walking for few moments, using the bathroom, sweating or shivering, etc), and the Basal Metabolic Rate (BMR) which indicates the minimum amount of calories that the body needs to perform necessary functions (such as pumping blood through the body, food digestion, breathing, temperature regulation, growing hair and skin, etc) [2,4]. Usually, RMR is a better indicator of daily energy needs and it is always slightly higher than BMR [4]. There is still little comparative data on the influence of sex, age, and obesity status on BMR and RMR. But several studies in the literature have shown diversities in RMR between men and women, obese and non-obese adults, and possibly racial/ethnic differences [5,6] and older adults (>70 yrs) compared to younger adults [7]. The estimation of body composition is often conducted with Indirect Calorimetry (IC), a non-invasive method determining the nutritional requirements and rate of oxidation of nutrients such as carbohydrates, fat, and protein. It analyzes the lungs' inhaled and exhaled air to evaluate oxygen consumption and carbon dioxide production [8].

Moreover, it is possible to evaluate raw bioelectrical parameters [9,10]. This evaluation can be performed through the Bioelectrical Impedance Analysis (BIA) or the Bioelectrical Impedance Vector Analysis (BIVA), in which the parameters are represented as a vector within a graph [11].BIA and BIVA are probably the most popular methods used to assess body composition, primarily because of the combination of cost-efficiency, user-friendliness, and portability [12] They employ bioimpedance-based predictive equations to estimate and monitor changes in body composition parameters such as fat mass, total body water, and muscle mass [13]. According to these methods, an electric alternating current (usually 50Hz) to assess the intra and extracellular water ratio and distribution is used. Specifically, the representative value in BIA/BIVA is the Impedance (Z) that measures the ease of an alternating current to flow in an electric circuit (the body). It is calculated as a relationship between two values. First, the Resistance (R or Rz), the force that a biological conductor opposes to an alternating current attributable to intracellular and extracellular fluids. Second, the Reactance (Xc), is produced by the additional opposition to the current from the capacitance or storage effects of cell membranes, tissue interfaces, and structural features [14,15]. The bioelectrical phase angle (PhA) is another relevant value that represents a qualitative approach to the body composition analysis assessed by BIA/BIVA and is calculated as the arctangent of $Xc/R \times 180°/\pi$ [16].

Graphically, it is represented as the angle between the vector and the x-axis [17] and it is considered a nutritional status index [18] because it is an indicator of cell membrane integrity and extracellular/intracellular water (ECW/ICW) ratio [19,20]. Recent studies on obese people have considered PhA and its relationship to altered health status conditions, suggesting it as a biomarker to quantify inflammation, and so high-risk patients [21,22]. In particular, it has been shown that obese women with a low PhA tend to have higher FM, higher levels of glucose, and higher cardiovascular risk factors [10]. The issue is relevant to public health institutions to develop specific preventive and supporting programs. Monitoring the body composition and appropriately assessing it, allows for an accurate evaluation of the population's nutritional status [23] and targets the most fragile group of individuals, such as the elderly, pregnant women, obese people, etc. [24] Indeed, obesity in the abdominal area has been found to be a major independent risk factor in the development of a range of cardiometabolic conditions [25]. Consequently, waist circumference (WC) reduction of at least about 3% in the younger (<55 years) men and about 5 % in the older (≥55 years) non-diabetic Japanese men with abdominal obesity can reduce the chance of development of type 2 diabetes mellitus. These findings suggest that the extent of WC reduction necessary for the minimization of diabetes risk is different among the different age groups [26].

In this study, we propose an innovative use of electromagnetic waves to stimulate metabolism and improve the patient's general health condition. Indeed, correcting and implementing nutrition strategies need to be integrated with physical activity and muscle toning. For this reason, we decided to treat a group of patients using Flat Magnetic Stimulation (FMS) technology to evaluate its effect on their metabolism and body parameters. We compared and combined the post-treatment measurements with the indirect calorimetry and BIA/BIVA to have an exhaustive evaluation of the specific characteristics of every subject. The reliability and quality of these kinds of devices have been investigated in many studies [27-29] and used in research to determine energy intake for various populations [30,31]. They are portable and functional solutions in clinical and non-clinical environments. These strategies are crucial if we consider the new millennium health problems and epidemics related to non-transmissible diseases (i.e., growing diabetes and prediabetes conditions epidemic) [32]. We think that using FMS technology could be a valuable strategy for weight control and maintenance, especially in patients that are not able to move properly (elderly), or as an integration for people who have high BMI and need to lose a lot of weight, or support for people who need to maintain a strict body condition such as athletes.

## Materials and Methods

Throughout the study duration, the side effects check and evaluation was performed to assess the protocol's feasibility.

## Study population

For this study, 10 women were enrolled. We decided to have a uniform population as much as possible and considered just women with a BMI assessed in the normal-weight range (or just slightly out of it). Indeed, they were between 32 and 56 years old and with a BMI ranging from 18.4 kg/m$^2$ to 25.6 kg/m$^2$ and a mean height (H) of 162.0 ± 4.8 cm. The patients did not change their lifestyle or diet during the study.

## Study Design

Eight sessions with Schwarzy, two per week, were carried out for every patient for a total of 4 weeks of treatment (see Figure 1 for the study timeline). Then, at the same timepoint, functional measurements were taken with BIA 101/BIVA Pro (Akern Srl, Florence, Italy) for the whole population and with Fitmate (Cosmed, Rome, Italy) for 50% of the subjects. The first device uses electrodes on the body surface while the second employs face masks and antibacterial filters to obtain specific measurements.

Assessment methods


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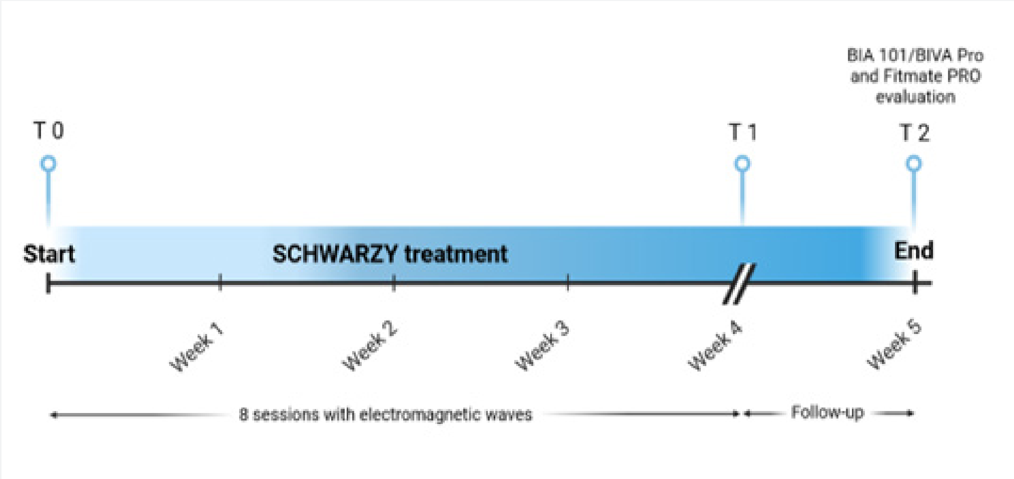


**Figure 1:** Study timeline. Patients were treated with electromagnetic wave fields for 4 weeks (2 treatments/week, from Time 0 to Time 1). Then, after 1 week of follow-up (Time 2-5 weeks from the study beginning), functional measurements with BIA 101/BIVA Pro and Fitmate were observed.

## BIA 101/BIVA Pro (Akern Srl, Florence, Italy)

The direct segmental technology (total body) impedance measurements were performed with a bioimpedance analyser (BIA 101 Anniversary, Akern, Florence, Italy) at a frequency of 50kHz. The accuracy of the BIA instrument was validated before each test session following the manufacturer's instructions. The participants were assessed in the supine position with legs (45° compared to the median line of the body) and arms (30° from the trunk) abducted. After cleansing the skin with alcohol, two electrodes were placed on the right hand and two on the right foot. In detail, disposable pads consisting of a sheet of conductive material (metal sheet) covered with a layer of gel of a fixed and defined thickness were used. Bioelectrical impedance vector analysis was carried out using the classic BIVA methods [11,33] Bioelectrical variables were analyzed in relation to the distribution of the reference population (through tolerance ellipses). Moreover, additional measurements were taken such as the Fat Mass (FM) and the Fat-Free Mass (FMM).

## Fitmate (Cosmed, Rome, Italy)

RMR was determined by using the Fitmate (Cosmed, Rome, Italy) instrument. It is a portable indirect calorimetry (IC) metabolic analyzer designed to measure oxygen consumption and resting metabolic rate (RMR). This instrument uses a turbine flow meter that is located at the end of a disposable face mask for measuring the respiratory minute volume. In this study, participants underwent an evaluation in the morning, not having eaten large meals the day before or strenuous exercised for 24h or drunk caffeinated beverages and medications before the RMR measurement [34-36]. Otherwise, the RMR values will likely be higher than the subject's actual RMR and the test should be repeated at a later time. Subjects sat quietly for 20 minutes prior to testing, then they were asked to put the Fitmate mask on their nose and mouth and sit in a supine position in a quiet room for 15 minutes. Calibration was done automatically for every measurement [36].

## Study device and protocol

SCHWARZY (Deka M.E.L.A., Florence, Italy)

The device system is widely used in the medical routine for body fat reduction, remodelling [37] and muscle-toning [38,39]. The patients were treated with the device using the Flat Magnetic Stimulation (FMS) technology, which made the muscles move without brain involvement thanks to up to two paddle handpieces applied on a specific body area (in this study the abdomen was treated with the elliptical handpiece called "Ellipse" and buttocks were treated with two round pads called "Flat" at the level of trochanters). The patients were treated for 8 sessions (4 weeks, 1 week of follow-up) for 30 minutes on average per session and adopting different protocols in sequence. The technology provides for three types of different protocols: aerobic, muscle shaping, and muscular strengthening and it is customizable based on muscle condition, adapting to the needs of each type of patient. Moreover, every protocol is characterized by low-frequency steps at the beginning of the treatment as a warming-up and at the end for cooling down and preventing lactic acid formation. For example, the "aerobic" is designed for untrained and sedentary people whereas, in "Muscle shaping" the muscles work to recover muscle


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thophism and tone. Indeed, it is recommended for subjects who do not perform regular physical activity (moderately active people). Eventually, "Muscle strengthening" is dedicated to trained subjects willing to increase muscle strength and build muscle mass.

## Results

No temporary muscular fatigue, muscle spasm, joint or tendon pain, local erythema or skin redness were reported. Means for the whole study population R, Xc, and PhA values were calculated at two time points (T0 and T2) with BIA 101/BIVA Pro while the RMR was calculated with Fitmate. R and Xc were normalised on the patients' height. Table 1 shows that R/H decreases when T0 and T2 measurements are compared indicating better body hydration. On the contrary, Xc/H registered a slight increase and so a softer tissue. Moreover, the PhA value raise was directly proportional to a positive trend change in the quality of the skeletal muscle mass as well as the intracellular/extracellular water ratio. RMR had also an improvement. Figure 2 shows the graphical representation of the BIVA evaluation. In addition, the IC was used on 5 randomly selected patients (5/10, 50%) in the study population for deeper metabolic evaluations. They were considered to prove that the estimated BMR values with BIA 101/BIVA Pro and Fitmate data were superimposable. This way, it was possible to further assess a considerable improvement in the metabolism with the RMR (see Figure 3) going from a mean value of 1300 (±221,2) to 1358 (±98,6) as shown in Table 1.

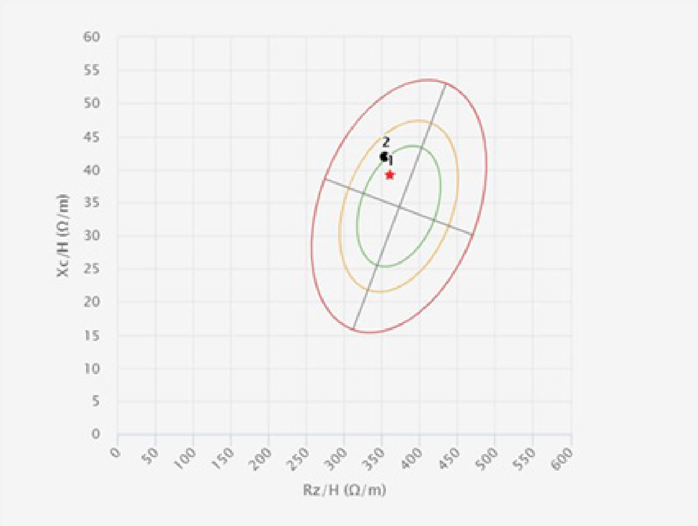


**Figure 2:** Vectorial representation of BIVA analysis for the study population. The R-Xc graph and vector displacements from before (T0) (red star, #1) to after (T2) (black dot, #2) the intervention period using the mean R/H and the mean Xc/H plotted on the reference population tolerance ellipses are shown.

**Table 1:** The means with standard deviation of the study population's body electrical values measured with BIA 101/BIVA Pro and the RMR measured with Fitmate are shown. The Resistance (R) and the Reactance (Xc) obtained with BIA 101/BIVA Pro were normalized using the patient height (H). Every parameter was evaluated at T0 (start of the experiment) and T2 (5 weeks from the experiment beginning). The standard deviation is reported for every value.

| | BIA 101/BIVA Pro | | | | | | Fitmate (50% population) | |
|---|---|---|---|---|---|---|---|---|
| | R/H (Ω/m) T0 | R/H (Ω/m) T2 | Xc/H (Ω/m) T0 | Xc/H (Ω/m) T2 | PhA (°) T0 | PhA (°) T2 | RMR (kcal/die) T0 | RMR (kcal/die) T2 |
| **MEAN** | 360,3±23,5 | 353,6±22,6 | 39,1±5,4 | 41,9±5,7 | 6,23±0,92 | 6,78±0,89 | 1300,0±221,2 | 1358,2±98,6 |

Some relevant exemplifying case studies are shown below and in detail in Table 2:

a. A 32-year-old woman, slightly underweight (BMI 18.4 kg/m$^2$), 165 cm high, sedentary. Measurements with IC showed a significant increase of 252 kcal/die in the RMR even if the subject was minute and no relevant change was expected. Moreover, the PhA increased after treatment and so did the quality of the muscle.

b. A 46-year-old woman, normal-weight (BMI 23.3 kg/m$^2$), 153 high, sedentary. Measurements revealed a reduction in FM but a considerable increase of 122 kcal/die in RMR.

c. In general, R (/H), Xc (/H), and FM decreased for all the double-tested patients. On the contrary, PhA and FFM increased as well as the RMR.

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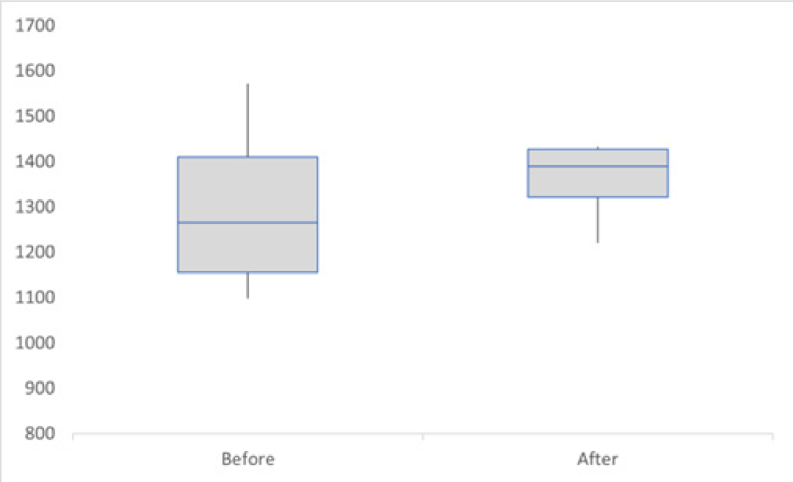


**Figure 3:** Graph of RMR value quartiles (kcal/die) of a representative group of population (4 patients) before and after the treatment. A general improvement in metabolism is visible after the treatment with a sensible reduction in the range of values when compared to the median.

**Table 2:** Summary of two case studies considered as an example. General characteristics and detailed measurements are shown. The Resistance (R) and the Reactance (Xc) obtained with BIA 101/BIVA Pro were normalized using the patient height (H). Also, the PhA, FFM, and FM are reported. RMR was estimated with the Fitmate (just for 50% of the population study). *LF=lifestyle (S=Sedentary).

| | General info | | | | BIA/BIVA Pro | | | | | | | | | | Fitmate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pt | Age | Sex | BMI (kg/m²) | LF | R/H (Ω/m) T0 | R/H (Ω/m) T2 | Xc/H (Ω/m) T0 | Xc/H (Ω/m) T2 | PhA (°) T0 | PhA (°) T2 | FFM % T0 | FFM % T2 | FM % T0 | FM % T2 | RMR kcal/die T0 | RMR kcal/die T2 |
| **1** | 32 | F | 18.4 | S | 355,6 | 340,7 | 40,0 | 39,7 | 6,4 | 6,6 | 86,4 | 87,6 | 13,6 | 12,4 | 1174 | 1426 |
| **2** | 46 | F | 23.3 | S | 348,0 | 347,8 | 40,1 | 41,3 | 6,6 | 6,8 | 77,3 | 78,2 | 22,7 | 21,8 | 1098 | 1220 |

## Discussion

In our study, BIVA and indirect calorimetry techniques were confirmed to be valuable tools for assessing patients' body measurements and characteristics. Nevertheless, in the scientific community, some concerns are recently raised about using BIA/BIVA. First, many devices with different technologies are currently used and a comparison between devices cannot always be made. Indeed, each device with its own technology outputs a range of values, depending on the sampling frequency and the device's reliability [13,40-42]. Second, the procedures are not standardized, and the different electrode placement, body position, calibration, nutritional status, skin preparation, circadian rhythm, and acute training status could be factors affecting the results. Lastly, some devices provide raw data to be inserted into regression equations, while others output the body composition parameters, limiting the possibility of a further qualitative analysis [13,40-42].

At the same time, it is important to emphasize that BIA/BIVA is easier to use than IC. This is why in this experiment, a double-deepened measurement with both techniques was carried out on half of the population as a further confirmation. Furthermore, IC usually requires a 12 to 24 hours fasting/light meals protocol and a period of at least 15 min in resting conditions for the functional measurements [36]. Meanwhile, in BIA/BIVA, the recommendation for the test is 2 hours of fasting without drinking water, and the test takes approximately 2 min. So, it is intuitive how IC has more unpredictable variables along the process. Indeed, the results largely rely on the patient's understanding and compliance with the exam and device functioning. Nevertheless, our results showed a full agreement between the data of BIA 101/BIVA Pro and Fitmate. When the study device is considered, there is not much data in the literature in support of the use of electromagnetic fields to stimulate body metabolism. At the moment, the TOP FMS technology is routinely used for other purposes such as in aesthetic medicine for muscle toning and fat reduction [43-45] and in urology and gynaecology for the treatment of urinary incontinence, persistent vulvar pain and vulvodynia, and other disorders and dysfunctions with remarkable results [46,47].


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The strategy we proposed, for example, may be useful as an improved measure of obesity-related risk in clinical and field settings to monitor and reduce BMI and WC in obese subjects [48]. Indeed, the measurement of the abdominal circumference and its reduction/increase is an important predictive factor regardless of the BMI value which can be obesity, overweight or normal [49]. With these bases, we broaden the application spectrum of the overmentioned technology and demonstrated that significant results were visible from the first treatment for the total population at the end of the experiment. Moreover, when the patients showed improvement in nutritional parameters and so in muscle tone and the aesthetic aspect, even compliance with the treatment was higher. This research lays the groundwork for further investigations and a better understanding of the possible applications of electromagnetic fields in nutrition medicine.

## Limitations

It would be crucial to include a standardised and qualitative patient evaluation of satisfaction and comfort perception in future studies.

## Conclusion

Study results showed that our innovative strategy led without discomfort or side effects to a significant improvement in RMR and bioelectrical parameters regardless of the patient's BMI. Thus, the devices we used for assessment and treatment represent valuable and effective supports that could be widely employed in nutrition medicine.

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