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ORIGINAL RESEARCH

VARIATIONS IN METABOLISM AND BODY COMPOSITION ESTIMATES THROUGHOUT A DAY

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ABSTRACT

Background: Values of resting metabolic rate are very important for determining optimal daily caloric intake. Body fat percentage is one of the most important indicators of health. However, there are possibilities for making mistakes in estimating these values. This study aimed to investigate possible variations in metabolism and body composition estimates throughout a day, depending on the time of the day the measurement is conducted.

Methods: 20 male adults (age=24.3±3.3 years, height=180.8±5.6 cm, weight=80.3±8.3 kg) completed three resting metabolic rate and body composition tests during one day, in the morning (8 am) after waking up and fasting from food, caffeine and alcohol for 12 hours, in the middle of the day (1 pm) and in the evening (5 pm). All participants followed a self-selected diet throughout the day in addition to fasting 2 hours before the middle of the day and evening measurements.

Results: The test results and comparison have shown significant ($p \leq 0.05$) differences between morning resting metabolic rate and middle of the day and evening resting metabolic rates. Resting metabolic rate estimations (8670±1581 kJ) were lowest in the morning and more closely approximated to the basal metabolic rate estimation (8660±774 kJ) of the bioelectrical impedance analysis. Results obtained using skinfold measurements to asses body composition showed no statistically significant difference ($p > 0.05$) depending on time of measurement. The only significant differences in body fat estimations over the course of the day, though small (~0.8%) were from bioelectrical impedance analysis.

Conclusion: Morning assessments were lowest regardless of the measurement, and body fat estimates via skinfold calliper do not appear to be as affected when measured multiple times within the same day as do body fat estimates via bioelectrical impedance analysis.

Keywords: resting metabolic rate, skinfold, bioelectrical impedance analysis, Tanita

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INTRODUCTION

Basal metabolic rate (BMR) and resting metabolic rate (RMR) are indicators of the amount of calories a person needs during one day. Values of BMR provide information on how many calories a person requires while fully inactive, but the guidelines for measuring BMR are very restrictive and require strict adherence to protocols. RMR values provide information on the amount of calories a person requires for basic body functions and also the amount of calories consumed by food intake. Resting metabolic rate guidelines are less restrictive than those of BMR and are more easily obtained. There are many predictive equations for estimating RMR, but research has shown that these equations often dramatically under- or over predict a person's RMR.[1-4] Measuring RMR using a combination of systems (e.g. Harris-Benedict equation and indirect calorimetry) has shown to provide more accurate data compared to different equations.[5,2] In regards to measuring RMR, there are many factors that can affect the final values. Physical activity, food, alcohol, caffeine, and nicotine affect RMR for a variable number of hours after consumption; therefore, intake of these items must be controlled before measurement.[6,7] Wrong calculations can significantly harm the effectiveness of a nutrition program, and can cause changes in body weight as well as dissatisfactory training results. Until recently, one of the few available ways for the general population to calculate their RMR was using various equations. But lately more and more systems are accessible. Resting metabolic rate can be assessed using breath-by-breath gas analyser. This method has become more accessible in recent times and can be found in hospitals, clinics and in diagnostic centres. In spite of their accessibility, professionals are prone to make mistakes in the protocol of testing RMR due to the inherent variability in repeated tests. In order for the system to work optimally and to ensure appropriate application and interpretation, there is a need to optimise the conditions of testing.[8] It is important to note that there is a possibility of error for the system components even when the test conditions are optimised.

Body fat levels, levels of high-density lipoprotein (HDL), low-density lipoprotein (LDL) and glucose in the blood are some of the most important health indicators. General range of body fat percentage for men is about 10-25% and for women 18-30%.[9,10] It is well established that excess body fat, particularly when located around the abdomen, is associated with hypertension, the metabolic syndrome, type 2 diabetes, stroke, coronary artery disease, and hyperlipidemia.[11] In addition, although we face risks when our body fat percentage is too high, we face another set of risks when the percentage is too low. When we drop below the minimal recommended levels of essential fat we negatively affect the ability of the reproductive system to function, and overall well-being.[12] Essential body fat is present in the nerve tissues, bone marrow, and internal organs (all membranes), and we cannot lose this fat without compromising physiological function. Essential body fat is approximately 3% of body mass for men and 12% of body mass for women.[13] There are many ways to measure body composition, including Dual-energy X-ray absorptiometry (DXA), underwater weighing, whole body air displacement plethysmography and others. These methods are costly and the equipment is not easily movable. Skinfold testing (SKF) and bioelectrical impedance analysis (BIA) are not expensive methods and have shown to produce results similar to DXA.[14,15,16] But in order to get the best results, adherence to pre-testing guidelines by the participant is very important.

The purpose of this study was to determine possible daily variations in results of three tests of RMR and body fat percentage with SKF and BIA throughout a day. We hypothesised that the results of RMR and body fat percentage with BIA would vary because of food and fluid intake throughout the day, and the results of body fat percentage with SKF would vary by a very small amount or stay the same.

METHODS

Participants

Twenty healthy, recreationally active men volunteered for the study. The participants mean ± SD age was 24.3±3.3 years, height=180.8±19.5 cm, weight=80.3±35.1 kg. The participants filled out a health history questionnaire when they first visited the facility, and gave written Informed Consent according to the Helsinki declaration. All of the procedures used in this study were approved by the Research Ethics Committee of the Diagnostic Centre.

Procedure

Body composition testing

Each participant was measured three times during one day. Participants came to the morning test after fasting from food, caffeine and alcohol for 12 hours. The morning test was performed at 8 am. Middle of the day test was at 1 pm and evening test at 5 pm. Participants fasted from food 2 hours prior to the middle of the day and evening tests. Participants did not do any strenuous exercise the day they were measured and had a self-selected diet.

On the day of the experiment, each participant came to the diagnostics centre and was tested for body composition. All measurements were conducted at the Human Performance Laboratory, according to the standards and instructions of the International Biological Program. Participants emptied their bladder and bowels in the 30 minutes before the BIA assessment. During the measurement the participant was in underwear. Morphological body measures were taken: body height and body mass, skinfolds of the chest, midaxillary, triceps, subscapular, abdomen, suprailiac and thigh. All measurements of skinfold sites were performed on the right side of the body with Harpenden skinfold calliper, England. Each site was measured three times and the average value was recorded for result determination. The skinfold sites were identified by measuring and marking sites on the body.. For calculating the body's density we used the 7 site formula [17] for body density (Body Density = 1.112 - (0.00043499 x sum of skinfolds) + (0.00000055 x square of the sum of skinfold sites) - (0.00028826 x age)). After the body density was calculated, the equation (%fat = 495/Body density – 450) [18] was used for calculating percent of body fat in a computer software (Excel; Microsoft Corporation, WA, USA). After the skinfold test was done, the participants were tested for body composition on the Body Composition AnalyzerAnalyser (BIA; Tanita BC-418 MA, Japan). For the assessment of total body weight, fat free mass and body fat percentage via the BIA, recommendations are that the participant spends 5 minutes prior to testing in the same position as during the test, for fluid stabilization and prevention of any variations in the results.[19] Before the assessment on the BIA each participant stood for 5-7 minutes. The participant stood on the scale barefoot in their underwear, and held the scale handles. Electrical current was released through the handles and through the standing part of the scale. Bioelectrical impedance analysis scale gave us the information on total body fat levels, lean and fat weight, water content and the ratio of fat and lean mass by body segments (trunk, left arm, right arm, left leg, right leg). Only one measurement on the BIA per testing was recorded i.e. three throughout the day.

RMR testing

COSMED QUARK CPET system was calibrated following the recommendations of the manufacturer. After the system was calibrated, a ventilation mask was placed on the participant. The mask allowed for mouth breathing. A strap was placed around the head to hold it in place. Before starting the test protocol the participant spent 5-10 minutes siting with the mask on to become accustomed to breathing through the mask. When the accommodating period was finished the RMR test started. During the test the participant was in a supine position for 16 minutes.. Upon completion of the test the ventilation mask was taken off., The first 6 minutes were discarded, and the RMR values were based on the ventilation of the last 10 minutes of the test. Values are presented as kilojoules per day(kJ/day). This procedure was repeated for each participant's three RMR assessments. Each participant completed all of his assessments on the same day. All subjects completed three tests of body composition using skinfold caliper, BIA on the Tanita scale and three tests of RMR on the COSMED QUARK CPET system.

STATISTICAL ANALYSES

Statistical analysis was done using Statistica for Windows 12.0. Statistical significance was set at $p \leq 0.05$. The data were normally distributed (Kolmogorov-Smirnov test; $p > 0.005$). Descriptive statistics was used for calculation of basic parameters for each variable: minimal (Min), average (Mean), maximum (Max) value and standard deviation (SD). For determining statistical time significance between variables we used one-way repeated measures ANOVA - analysis of variance and Bonferroni post hoc test. Significant main effects of time were further investigated through post hoc t-test comparisons with Bonferroni adjustments.

RESULTS

The data are presented as mean ± standard deviation.

The average results of body fat estimated with BIA were: morning tests 12.1±3.9%, middle of the day 11.3±4.4% and evening 10.9±3.9%. These results showed statistically significant difference ($F(2.38)=10.532$, $p \leq 0.001$) between measurements and average variation of 0.8% body fat.

The average results of body fat estimated with skinfold were: morning test 9.6±2.6%, middle of the day 9.6±2.6% and evening 9.7±2.6%. These results showed no statistically significant difference ($F(2.38)=2.7773$, $p > 0.075$).

The results of RMR have shown statistically significant differences between the first measurement compared to the second and third measurement. The results have shown average values of 8670±1581 (kJ/day) of the morning test, middle of the day test showed values of 10974±2753 (kJ/day) and the evening test values of 11162±886 (kJ/day), ($F(2.38)=21,410$, $p \leq 0.001$).

Comparison between the estimated BMR (8660±774 kJ/day) on the Tanita scale based on the participants characteristics (age, weight and height), and the results of morning tests of RMR (8670±1581 kJ/day) has not shown any statistically significant differences ($p>0.98$).

DISCUSSION

This study was designed to assess the variability of estimations of metabolic requirements and body fat percentage as assessed in the morning, at middle of the day, and in the evening of the same day. We hypothesised that the results of RMR and body fat percentage with BIA would vary, and the results of body fat percentage with SKF would vary by a very small amount or stay the same. The gathered results support our hypothesis.

RMR

Haugen et al. (2003) reported that the mean afternoon RMR was higher than the morning RMR

Table 1. Descriptive statistics and analysis of variance parameters of the RMR and percentage of body fat

Variable	Morning measurement mean±SD Min-max	Middle of the day measurement mean±SD Min-max	Evening measurement mean±SD Min-max	Degrees of freedom	F	P
RMR (kJ/day)	8670±1581 # * 5577-11422	10974±2753 7146-15878	11162±1886 7589-13752	2	21.410	0.001
%Tan	12.1±3.9 # * 7.3-22.2	11.3±4.4 4.1-20.2	10.9±3.9 4.8-19.5	2	10.532	0.001
%skin	9.6±2.6 5.9-14.9	9.6±2.6 5.5-14.9	9.7±2.6 5.9-14.8	2	2.7773	0.075

*Abbreviations: Mean – average, SD – standard deviation, Min – minimal value, Max – maximum value, p – significance level, # - the difference between the morning and middle of the day measurement p≤0,05, * - the difference between the morning and evening measurement p≤0,05, $ - the difference between the middle of the day and evening measurement p≤0,05*

Morning measurement – 8 am, Middle of the day measurement – 1 pm, Evening measurement – 5 pm

RMR – resting metabolic rate, %Tan – body fat percentage via BIA, %skin – body fat percentage via skinfold by approximately 418 kJ/d. Our study supports these findings even though we utilised a 2 hour fast prior to the middle of the day/afternoon tests as opposed to Haugen et al. (2003) who used a 4 hour fast. Differences in the duration of fasting before measurement are probably the leading reason why Haugen et al. (2003) recorded 6% difference between the morning and afternoon results, while our study recorded 22% differences. Reed and Hill (1996) report measuring thermic effect of food at 60% after 3 hours, 78% after 4 hours and 91% after 5 hours. We can see that the thermic effect of food decreases as fasting increases. As stated by Haugen et al. (2003) a 4- to 5-h fast may be adequate time to decrease the effect of the thermic effect of food on RMR measurements. Based on our findings we support these statements. Measuring RMR after 2 hours of fasting using Cosmed Quark Cpet system can lead to high discrepancies in recreationally active man. Still it is unknown if these results would be obtained in another sample size, or by using some other system for measuring RMR.

Skinfold

Results obtained in the percent of body fat by using skinfold showed no statistical significant daily variance affected by time of day. We may conclude that measuring body fat percentage in recreationally active men can be conducted regardless of the time of day. However, it is important that the participants and technicians adhere to established (International Society for the Advancement of Kinanthropometry) set of recommendations in order to get the highest possible precision.

BIA

Results obtained via BIA showed differences in body fat percentage, though small (~0.8%). We may hypothesize that the leading factor for this is food intake. As shown by Slinde and Rossander-Hulthén (2001) body fat percentage can be increased within 2-4 hours after a consumption of a meal because of the reduction of impedance. Results that we gathered support these findings, even though the differences in measured values were small. While the mean variations between the subjects were small, it is important to note that in 5 subjects there was a mean deviation between 1.5-2.2% of body fat. Individual differences are present but we may conclude that it seems it would be best to limit food intake for >2 hours before the measurement of body fat via BIA in recreationally active men.

The limitations of this study are the following: only men were recruited, of approximately the same age, they had no standardized meals before each measurement and each subject was measured only for one day. For future research, we recommend that a sample of subjects consists of both men and women, that the participants have standardized meals and accurately track daily calorie intake, as well as to repeat the protocol for 2-3 days in a row in order to notice possible day-to-day variations.

CONCLUSIONS AND PRACTICAL APPLICATION

In the light of the results shown we conclude that RMR values and values of body fat percentage measured with BIA can vary depending upon the time of the day the measurement is conducted in recreationally active men. Based on our data and the literature review, the recommendations for testing RMR in recreationally active men on the COSMED QUARK CPET system are the following:

1. Individuals preparing for RMR measurement should refrain from eating, consuming alcohol and nicotine for varying times before measurement.[7]
2. Individuals should abstain from engaging in physical activity before testing, because physical activity increases calorie consumption and lipid oxidation.[22]
3. The lighting and the room temperature should be comfortable and relaxing.
4. The subjects should spend 5-10 minutes with the mask to accommodate their breathing before starting the test.

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