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# OVERESTIMATION OF BASAL METABOLIC RATE THAT RESULTED FROM PREDICTIVE EQUATION COMPARED WITH INDIRECT CALORIMETRY MEASUREMENT

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**Abstract :** We use predictive equation to calculate Basal Metabolic Rate (BMR) in daily practice. Hariss Benedict and McArdle equation are the most popular predictive equation. Nowdays, many researchers revealed overestimation of BMR by using such equation. Especially if we use those equations in Asia region. This research will investigate the overestimation of BMR resulted from predictive equation compared with indirect calorimetry measurement by using spirometry.

The subjects of this research are 17 persons, 5 man and 12 women. The age range from 18 till 19 years old. We use Fircroft Way Edenbridge Spirometry to do indirect calorimetry. The BMR resulted from Hariss Benedict and McArdle, respectively, 1420,5 $\pm$ 91,4 and 1285,8 $\pm$ 148,4 kcal per day, compared to the result of indirect measurement 1088,6 $\pm$ 367,3 kcal per day. This research revealed significant overestimation ($P<0.05$): 30,5 % resulted from Hariss Benedict equation and 18,1% resulted from McArdle equation.

**Key Word** : Basal Metabolic Rate, predictive equation, indirect calorimetry

## INTRODUCTION

The definition of basal metabolic rate (BMR) was a minimum rate of metabolism needed to maintain life and as a major component of daily energy needs (Payne & Waterlow, 1971). Metabolic rate measured in basal conditions : mental and physical rest, 12 hours fasting, and performed at a basalt temperature range (Garrow, 1978).

In daily practice, we calculate BMR using predictive equations. These equations generally contain variables of age, sex, and body weight (Dubois & Dubois, 1916). Reseachers find 10-11% overestimation resulted from those predictive equation if used in Asia. This, might be caused by racial factor (Henry & Rees, 1991). First overestimation was reported by Almeida in Brazil (1921), he found that direct measurement of BMR 24% lower than the predictive equation. Ismail et al (1998) also reported 9% overestimation in women and 13% in male Malaysian adults.

Overestimation of BMR calculation has an important implication, overestimation of minimum energy balance. Then, over-estimation can resulted in over energy intake in population due to a larger energy consumption estimated than necessary.

The aims of this study is to determine BMR overestimation resulted from predictive equations compared with indirect measurements. This study would also examine the relationship between body composition, body size, blood pressure, and metabolic rate measured by the indirect method. Information provided will be able to provide a more accurate estimation of BMR to total energy needs will be met with completely.

BMR is the amount of energy required to maintain function of vital organs during basal conditions. Technically, it means that the measurement should be done in a such

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condition, rest in supine position, fasting for 8-18 hours, normal body temperature (37$^o$C) in a neutral room temperature (27 - 29$^o$C) and without the pressure of psychological stress (Plowman, 2008 ).

Energy consumption at rest depends on the activity of vital organs. The liver consume the largest portion of rest energy (29-32%), followed by brain (19-21%), muscle (18%), heart (10%), lung (9%) and kidney (7%). Muscles require energy at rest in order to maintain their muscle tone. Mobile activity will involved sodium-potassium pump activity, synthesis and degradation of waste products, nerve impulses transmission, and secretion of enzyme and hormone (Bogert, et.al, 1973; Bursztein, et.al., 1989).

Metabolic rate were expressed in energy units per body surface, kcal per m$^2$; energy unit per day, kcal per day; oxygen volume per minute, $VO_2$ mL per minute. We use two first ones if we focus in the energy expenditure. Whereas, we will use the last option if we interested in oxygen consumption. The area of the body surface can be seen in the estimation table Body Surface Area (BSA) compiled by D. Dubois and EF Dubois (1916) (Plowman, 2008).

BMR measurement, in humans, could also be done by using spirometry or metabola-tor. This, utilize oxygen as a source of breathing air in a closed circuit with soda lime within the circuit. The consumption of oxygen in the tank will reduced oxygen volume in a certain period of time. We record total oxygen consumption in a period of time then convert it into equivalent energy (kcal) that consumed in the same period. We made corrections to the volume of oxygen based on Standard Temperature and Pressure values (STPD) (Plowman, 2008).

It is well known that similar to direct measurement of energy consumption, we can also calculate it using predictive equation. Predictive equations, generally, considered many variables such as body size (height and weight), gender, and age (Dubois & Dubois, 1916). Schofield then create a predictive equation that is more comprehensive and ultimately adopted by the WHO (1985). This predictive equation is sufficiently accurate to be used in the subtropical regions. It is easy to under-stand because the base populations in the development of predictive equations are populations in the subtropical regions, North America and Europe. The research shows overestimation of BMR that resulted from predictive equations compared to direct measurement with calorimetry. This overestimation is about 10-11% in the Asiatic race Hindians (Henry & Rees, 1991).

Possible explanation for this over-estimation is different climate. Changes in our surroundings stimulate adaptation mechanism that intended to keep the body within normal limits. For example, increasing body heat production will increase the value of BMR. Tropical regions have higher temperature than subtropics region. This condition would resulted a specific adaptation. Tropical population do not need extra heat production in order to maintain their body temperature. So, BMR in tropical region, theoretically be lower (Guyton, 2002).

Several predictive equations use variables that are easily to measure, such as body height, body weight, sex, and age. It could be seen in WHO equation and Haris-Benedict equation. McArdle equation use body composition as variable in calculation. Those equation can be seen below (Adiatmika, 2003).

1. Haris Benedict
   *Male*
   BMR = 66 + (13.7 x BW (kg)) + (5 X TB (cm)) - (6,8 XU (th))
   *Female*
   BMR = 655 + (9.6 x BW (kg)) + (1.8 X TB (cm)) - (4,7X U (th))

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2. McArdle
   BMR = 370 + 21.6 lean mass (kg)

Cardiovascular variables was used in Read, Read-Barnet, and Gale equation. Research by Ismail showed coefficient of determination of this equation is of 0.25 - 0.42, considered small. However, these findings correspond to the results of the WHO (1985) that obtain r2 values of 0.366 to 0.440 (Ismail, 1998). Other studies show that the relationship between BMR with independent variables of age, sex, body size will vary in different population. Seasonal patterns, diet, exercise and ambient temperature will also cause variations BMR (Plowman, 2008).
Factors influencing metabolic rate, among others, age, sex, body size, body composition and body temperature. Metabolic rate was found highest in the group of infants and children. The decline occurred since the age of 6 to 18 years. After this, it would be decreased more slowly. It is in line with the increased amount of body fat on a regular basis (Plowman, 2008). Metabolic rate is related to body surface area and the number of cells in the body. Obese person have larger surface area, larger number of cells - fat cells then normal person. So, don't be surprised when obese people has greater metabolic rate than those of normal weight (Jequier, 1987).
In general, women's group will have a lower BMR than men. This caused, mainly, due to smaller organ size in female than male. The other is a trend that female has smaller body than the male. The most plausible explanation is lesser muscle tissue and larger fat in women. Increasing in body fat will lowering BMR; each 1% will lose 0.6 kcal per day (Bogert, et.al., 1973; Bursztein, et.al., 1989).
In practice, found a discrepancy BMR using predictive equations when compared with direct measurement method. Eighty-five percent of the subjects would have a BMR in the range of 10% of the value obtained from the predictive equation. The rest (15%), will have a BMR in span may be greater or smaller. A person who has a higher BMR than the average can only consume more calories without fear of overweight, so do the opposite (Bursztein, et.al., 1989; Guyton, 1997).
Other factors that influence the BMR is body temperature. For every degree increase in body temperature, metabolism will increase as much as 13%. Decreasing in body temperature, will be followed by the reduction of energy consumed (Plow-man, 2008).

## RESEARCH METHODOLOGY

The design of this study was cross-sectional analitic study. The sample of this study were 17 adults, ages between 18-30 years. Research carried out in May 2013, in the Faculty of Medicine-Udayana Uni-versity, Denpasar. Device and method of measurement are as follows: MIC Weighing Health Scale, MIC Health Mea-surement Scale height, John Bull British Indicators LTD metal calipers, sphygmo-manometer and Stethoscope, Fircroft Way Edenbridge Kent TN86HE Spirometer, model No. 50-1817.
BMR is the speed of the usage of energy in basal conditions, measured by metabolator. Body composition and muscle fat compo-sition is determined by measure thickness of skin folds, determined with metal caliper. Body height derived from measurements using MIC high gauge weight (0.1 cm). Body weight derived from the measurements by using MIC scales (0.1 kg). Blood pressure is arterial blood pressure resulted from measurement at the end of the BMR measurement. Pulse pressure is the difference of systolic and diastolic blood pressure research subjects. Heart rate is the average pulse rate at the

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beginning and end of BMR measurements obtained by means of palpation in the radial artery. Body Mass Index (BMI) is an index derived from the body of the calculation of average height and weight.

BMR measurement, indirectly use metabolator. This method will have a closed circuit, 99.9% $O_2$ Inspired air and elimination of $CO_2$ with soda lime. Measurements carried out in the morning, at 6:00 to 7:00 am, in a room that has temperature of 25°C and 700 mmHg air pressure. Temperature and the humidity is maintained during the measurement. Research subjects were asked to fast for approximately 10 hours before the measurement is made.

## RESEARCH RESULTS AND DISCUSSION

Subjects who are willing to follow the study was 17 people, five men (29%) and 12 females (71%). Subjects have age range between 18-19 years with an average of 18,06 $\pm$ 0.25 years. Overall subjects met the criteria for inclusion and follow research to complete.

Table 5.1 Measurement of BMR

| No | Method | Average (kcal/day) | SD |
|---|---|---|---|
| 1 | Spirometer | 1088,6 | 367,3 |
| 2 | Harris Benedict | 1420,5 | 91,4 |
| 3 | McArdle | 1285,8 | 148,4 |

The BMR calculation on inspection and research subjects are presented in Table 5.1. It could be seen on the table that the average BMR resulted by metabolator is 1088.6 + 367.3 kcal per day. BMR resulted by predictive formulas Hariss Benedict and McArdle respectively 1420.5 $\pm$ 91.4 and 1285.8 $\pm$ 148.4 kcal per day.

Table 5.2
The Analysis Hariss Benedict Equation and Spirometry

| No | Method | Rerata | SD |
|---|---|---|---|
| 1 | Spirometry | 1088,6 | 367,3 |
| 2 | Hariss Benedict | 1420,5 | 91,4 |

t value = 0,004; P = 0,05

BMR determination using predictive equation will then be compared with spirometry as the standard measurement of BMR. Difference or difference of any inspection or measurement techniques are presented in Table 5.2 and 5.3.

BMR resulted by Hariss Benedict equation is 30.5% greater than the measurement resulted from metabolator. Overestimation of this Haris Benedict predictive equation is 331.9 kcal per day. Statistical test use paired student t test and proof a significant differences ($P \leq 0.05$).

Table 5.3
The Analysis McArdle Equation and Spirometry

| No | Method | Rerata | SD |
|---|---|---|---|
| 1 | Spirometry | 1088,6 | 367,3 |
| 2 | McArdle | 1285,8 | 148,4 |

T value = 0,03; $P \leq 0,05$

BMR determination resulted by McArdle is 18.1% higher compared with measure-ments using metabolator, average overestimation by McArdle equation is as large as 197.3 kcal per day. The statistical test revealed a significant differences ($P \leq 0.05$).

In men with measuring spirometer found the average BMR of 1452.9 kcal per day. The average is lower than the calculation by using a predictive equation. Difference of 35.0 kcal per day was found in the calculation by using Hariss Benedict equations and of 22.1 kcal per day in McArdle equation, in other word is 2.4% and 1.5% lower. In woman we found that the average of BMR with metabolator measurements is 926.6 kcal per day. These values 50% lower than results obtained by Hariss Benedict predictive equation and

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29.6% lower than results obtained by the McArdle equation.

Correlation made between the variable composition of fat with BMR shows the relationship of 0.16. This indicates that in this research body composition has no influence to the metabolism speed. Theoretically, high fat composition will cause lowering metabolism rate, so do the opposite (Plowman, 2008).

Differences that occur in the calculation by utilizing a predictive formula and measurement by spirometry according to predictions or hypotheses posed. Several factors influence the differences among body composition, differences in hormonal activity, and the difference between the population of a tropical climate with subtropical regions population.

Several previous studies also indicate the same thing. Overestimation was estimated around 10-11% in the Asiatic race Hindians (Henry & Rees, 1991). Almeida research in 1998 showed differences in BMR in the Brazil reach 24%, and Ismail research shows the difference of 9% in women and 13% men. Differences found in this study is greater than with the study. This study found differences in the range between 18 and 30% are found in two general predictive equations used, Hariss Benedict equation and McArdle.

Sex variable give you a sight that differences in women group is greater than men group. Differences in the group of women reached 50% in the calculation of the formula Haris Benedict. Whereas the male group showed a difference of only 2.4% in the same equation. But in general the results in the group of women was lower than the results of calculating the male group.

Benedict utilize predictive equation from Hariss with body size factor, consisting of height, weight, and age to determine the magnitude of BMR. Whereas in equation McArdle exploit the non-fat component (non-lean mass) as a decisive factor BMR. Seen in this study that McArdle equation yields approaching measurement using spirometry. This is consistent with the theory which states that the speed of metabolism is influenced by body composition and total body fat. The higher the fat content of the body then the speed of one's metabolism will be lower, but so are (Plowman, 2008).

Factor of body size on Hariss Benedict equation with yields approaching examina-tions with spirometry. This may be due to the factors used in the calculation of this equation, the size of the body. Body size does not reflect the composition of the body itself, does not provide information or take the composition of the fat and non-fat in the body. Whereas muscle com-ponents or non fat determines the speed of one's metabolism (Plowman, 2008).

## CONCLUSIONS AND RECOMMENDATIONS

We found that the value of BMR overestimated by Hariss Benedict and McArdle predictive equation, respectively 30.5% and 18.1%. Body composition plays important role in determining BMR. This results need further step by using direct calorimetri and broader age grouped sample.

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