CHAPTER 1.

INFORMATION ABOUT NUTRITION AND ENERGY EXPENDITURE

1.1 Introduction

Maintaining the correct contesting body weight is of enormous importance for athletes. The irrational consumption of calories results from the accumulation of superfluous fat in quantities that exceed the desirable level. The maintenance of low body fat proportion (5-12% of total body weight), necessary presupposition in championships imposes the strict control of calories, which are consumed on a daily basis. We should not ignore that the fat tissue is not active; this means that it does not participate directly in the production of mechanic work, but only indirectly as a source of energy. Calories in the form of fat are stored up in the fat tissue, in order to be used by the body. To be more precise, every gram of stored fat corresponds to 9.2 k-calories. This means that an athlete, who weights 70 kilos and has 6% fat, has 4.2 kilos fat or 38.640 k-calories. This amount of energy is enough for 13-14 days. The maintenance of low body fat proportion does not help the athlete only in appearance, which is a necessary presupposition for certain sports, but in performance as well, since the body moves with greater ease and, therefore, performs better.

The presence of every extra kilo of fat in the body, besides what is necessary for maintaining the athlete's health, prevents the athlete from having the best possible appearance. Therefore, it is a fact that the reduction in body fat results to better performance (Pavlou, 1992).

1.2 REE (BMR)

It is a desire of most trainers to want to keep their athletes with the correct body weight. In order to calculate the daily calorie needs, the trainer should take into consideration three parameters.

a) The athlete's daily calorie needs in position of tranquility (resting energy expenditure denoted as REE or basal metabolic rate denoted as BMR).

b) The daily calorie needs for routine activities (denoted as DEE) and

c) The daily calorie consumption (burning) during training (denoted as AEE). Resting energy expenditure represents the amount of calories required for a 24-hour period by the body during a non-active period. This is the amount of energy a person's body can burn if they slept all day (24 hours).

1.3 REE estimation

Energy expenditure can be estimated by numerous published formulas. There are nearly 200 published energy expenditure formulas dealing with various conditions, disease states, age, presence of obesity and other additional factors (McClave and Snider, 1992). One of the most frequently used formulas for predicted energy expenditure is the Harris-Benedict equations (Harris and Benedict, 1919). These were established in 1919 and took into account gender, age, height and weight. However, these formulas are skewed towards young and non-obese persons (Frankenfield, 1998).

The Harris-Benedict Equations are the following:

REE = 66,5 + 13,8 weight + 5,0 height – 6,8 age for males and

REE = 665,1 + 9,6 weight + 1,8 height – 4,7 age for females,

where REE is measured in calories per day, weight is measured in kilograms, height is measured in centimetres and age is measured in years.

The Harris-Benedict equations have been found to overestimate the actual energy expenditure measurements by 6% to 15%, through the use of indirect calorimetry* (Garrel, 1996). There is a large variation between individuals, when the measured energy expenditure is compared with the estimated amount. These equations have limited clinical value when tailoring nutrition programs for specific individuals for weight loss purposes or acute as well as chronic illness feeding regimens.

Energy expenditure can be measured directly and accurately by placing a person in a calorimeter and measuring the amount of heat produced by the body mass. This is expensive and very impractical in the clinical setting. Energy expenditure can be measured indirectly with a metabolic cart by analysis of respired gases (usually expired) to derive volume of air passing through the lungs, the amount of oxygen extracted from it (i.e., oxygen uptake

* Special equipment that accurately measures the resting energy expenditure of human individuals.

VO_2) and the amount of carbon dioxide, as a by-product of metabolism, expelled to atmosphere (CO_2 output – VCO_2)– all computed to represent values corresponding to 1 minute time intervals. With these measurements the resting energy expenditure (REE) can be calculated (Pavlou, 1992). The abbreviated Weir equation is used to calculate the 24-hour energy expenditure (Weir equation is described below). The metabolic cart prints out these measurements after completion of the indirect calorimeter test.

The Abbreviated Weir Equation is given as:

$$REE = [3{,}9\ (VO_2) + 1{,}1\ (VCO_2)]\ 1{,}44$$

$$VO_2 = \text{oxygen uptake (ml/min)}$$

$$VCO_2 = \text{carbon dioxide output (ml/min)}$$

To provide the best results when measuring REE, certain conditions have to be controlled whereas others need to be documented at the time of the test. During the test, the individual is interfaced with a metabolic measurement system by means of a facemask or a canopy. A mouthpiece with a nose clip is also sometimes used, but it may create overly stressful conditions to a subject (patient).

Important considerations or conditions to improve the REE measurement are as follows:

1. The individual should rest for at least 30 minutes in a bed or a recliner before the test. However, the person should not be asleep.
2. No food for at least 2 hours before the test.
3. Maintain quiet surroundings when the test is in progress and normal temperature. The individual should not move their arms or legs during the test.
4. Normal room temperature should be maintained, avoid drafts or any condition that might result in shivering.
5. Medications taken should be noted, such as stimulants or depressants.
6. Steady state should be achieved, which would be identified clinically by the following: 5 minute period when average minute VO_2 and VCO_2 changes by less than 10% Stable interpretable measurements should be obtained in a 15 to 20 minute test.

1.4 Factors that affect REE

REE is the minimal caloric requirement needed to sustain life of a resting individual. Some factors that affect REE are the following (Black et al, 1996):

- Age: In youth, the REE is higher; age brings less lean body mass and slows the REE.
- Height: Tall, thin people have higher REE.
- Growth: Children and pregnant women have higher REE.
- Body Composition: The more lean tissue, the higher the REE. The more fat tissue, the lower the REE.
- Fever: Fever can raise the REE.
- Stress: Stress hormones can raise the REE.
- Environmental Temperature: Both the heat and cold raise the REE.
- Fasting/Starvation: Fasting/starvation hormones lower the REE.
- Malnutrition: Malnutrition lowers the REE.
- Thyroxin: The thyroid hormone thyroxin is a key REE regulator; the more thyroxin produced, the higher the REE.

1.5 Body Composition

It would be useful to see some characteristics about body composition as shown in table 1.5.1

Table 1.5.1 Body Weight distribution

	Male	Female
Muscle	45%	36%
Bone	15%	12%
Total Fat	15%	27%
Essential Fat (women need more)	3%	12% (mainly for reproduction)
Storage Fat	12%	15%
Other Tissues	25%	25%
Total	100%	100%

Elements that may affect these ratios are as follows:

1. Fitness Level and Exercise: usually leads to leaner body mass, which would increase REE and Energy Expenditure
2. Genetics: genes may predetermine body size and composition
3. Age: the younger, the leaner the body mass
4. Diet: less fat leads to less body fat
5. Gender: males, on the average, usually have less body fat

The Two basic components of body mass are:

1. Body Fat Mass (approximately 10% water)
2. Body Fat Free Mass (approximately 70% water includes lean body mass and essential fat)

There are various ways to obtain a measurement of your body composition, but most of these tests are inaccurate.

The following table separates individuals in 5 categories concerning fat proportion.

Table 1.5.2 Body Fat Ranges for individuals

	Males	Females
Exceptionally Lean	6-10%	10-15%
Very Lean	11-14%	16-19%
Lean	15-18%	20-25%
Moderate	19-24%	26-29%
Over fat	25%+	30%+

1.6 Total energy expenditure and physical activity levels

Over the past decade a new technique using stable isotopes has revolutionised the study of human energy expenditure. The doubly labelled water (DLW) method permits determination of energy expenditure of free-living individuals integrated over a period of, usually, between 7 and 20 days. The first data from humans were published in 1982 (Schoeller and Santen, 1982). Since then sufficient data have accumulated to form a basis for establishing energy requirements. A database of 1614 measurements in 1123 individuals aged between 2-90 years has been comprehensively analysed (Black et al, 1996).

Usage, validity and variability of the physical activity level (PAL) index

Total energy expenditure (TEE) is expressed as a multiple of REE to determine the requirements of adults as recommended by the last FAO/WHO/UNU Expert Consultation Report (1985) on energy and protein requirements. These multiples of REE are referred to as physical activity levels (PALs) and calculated by dividing TEE by REE. The expression of energy expenditure (or requirements) of adults as PALs provides a convenient way of controlling for age, sex, weight and body composition and for expressing the energy needs of a wide range of people in shorthand form.

The limits of human energy expenditure

Studies carried out under special conditions provide information on energy expenditure at the extremes of physical activity levels in adults and thus provide a frame of reference for evaluating values of TEE and PAL from the general population. These studies of TEE measurements using the DLW technique have been summarised by Black et al (1996). At the lower limit of physical activity, studies in non-ambulatory, chair bound subjects and in individuals confined to a calorimeter and apparently not exercising, provide a mean PAL of 1.21. This is slightly lower than the value of 1.27 suggested by FAO/WHO/UNU as the survival requirement. At the upper limit of physical activity there is a distinction to be drawn between the maximum achievable over a limited period of time and the maximum sustainable as a long-term way of life, given physical fitness and adequate food. The maximum achieved over limited periods of time was a PAL of >4.0 in a bicycle race and a polar exploration. The maximum for a sustainable way of life may be that represented by soldiers on active service, with a mean PAL of 2.4. These data suggest a PAL range of 1.2-2.5 for sustainable lifestyles, where 1.2 is indicative of a non-ambulant life style and 2.5 represents a very physically active lifestyle (Table 1.6.1).

Energy expenditure of free-living adults with normally active daily life

A total of 319 adults (212 non-pregnant non-lactating females and 107 males aged 18-64 years) were identified as healthy, free-living, leading a normal daily life, not recruited as having specific and special circumstances, occupations or activities, and in whom REE had been measured. The data fully encompassed the PAL range from: 1.2-2.5, established above as the likely range of sustainable energy expenditures (Table 1.6.1). The wide range of expenditures at any age was notable. Regression analysis of the entire data set accumulated by Black et al (1996), which included a total of 574 subjects aged 2-90 years on whom DLW data and REE measurements were available indicated that equations based on weight, height, age and sex can account for 77% and 86% of the variance in TEE and REE.

Table 1.6.1 Physical Activity Levels (PALs)

Life style and level of activity	PAL
Chair-bound or bed-bound	1.2
Seated work with no option of moving around and little or no strenuous leisure activity	1.4-1.5
Seated work with discretion and requirement to move around but little or no strenuous leisure activity	1.6-1.7
Standing work (e.g. housework, shop assistant)	1.8-1.9
Significant amounts of sport or strenuous leisure activity (30-60 min four to five times per week)	+0.3 (increment)
Strenuous work or highly active leisure	2.0-2.4

1.7 TEE – Calculation for athletes

In order to calculate TEE (total energy expenditure) the trainer should take into consideration the three parameters that already have been mentioned. Those parameters can be symbolized as: REE (resting energy expenditure), DEE (daily energy expenditure), AEE (activity energy expenditure) and TEE (total energy expenditure).

REE: Resting expenditure energy can be accurately measured by direct or indirect calorimetry, but it is simpler, in practice, to use predictive equations. The equation has to be representative of Greek elite athletes since both ethnic and physical conditions are important factors that influence REE.

DEE: Daily energy expenditure can be calculated by the multiplication PAL × DEE where PAL (physical activity level) has to be very low (PAL = 1,2) because an elite athlete besides training should not do anything that would be exhausting.

AEE: Activity energy expenditure is the calory consumption during training. AEE depends on many factors. Some examples are, the body weight, the type and intensity of the training, the duration of the training, the environmental temperature, the altitude etc. Under normal circumstances, the most important factors are the body weight (Kg), the duration (min) and the intensity of the training (% VO2max). There are special tables (Table 1.7.1) with constants about every type of sport and training that provides the training activity level TAL. Multiplying the training time in minutes, with the consumed calories per minute of training, with the same intensity, and this multiplied by the body weight in kilos, equates to the calories consumed during training. To calculate AEE we use the following simple formula:

$AEE = WEIGHT \times TIME \times TAL$

Table 1.7.1 Training Activity Levels (TALs)

Ping-Pong	Training	0,069
	Competition	0,125
Tennis	Training	0,115
	Competition	0,210
Weights	Weight Training	0,080
	Weight Lifting	0,138
Walking	3 Km/h	0,048
	5 Km/h	0,064
	6,5 Km/h	0,083
	8 Km/h	0,119
Running	7 Km	0,110
	11 Km	0,190
	12 Km	0,200
	14 Km	0,223
	16 Km	0,250
	21 Km	0,289
	Jogging 7 Km/h	0,139
	Stretching	0,024
Basket Ball	Training	0,132
	Competition	0,185

Football	Training	0,132
	Competition	0,170
Volleyball	Training	0,085
	Competition	0,112
Squash	Training	0,138
	Competition	0,212
Swimming	Medium Impact	0,128
	High Impact	0,156
Cycling	9 Km/h	0,064
	15 Km/h	0,100
	30 Km/h	0,130
	40 Km/h	0,150
Aerobics	Medium Impact	0,078
	High Impact	0,129

TEE: Total energy expenditure can be easily calculated, if we know REE, DEE and AEE, by the simple equation

$$TEE = REE \times 1{,}2 + AEE \text{ or } TEE = DEE + AEE.$$

Therefore, if an athlete wants to achieve the ideal body weight for his/her sport by increasing or reducing his/her body weight, he/she should first calculate TEE. It is significant to note that the methods used to achieve the "weight- goal", not only reduces the athlete's competing ability, but at times may place the athlete's health in danger.

In every effort to increase or reduce the athlete's body weight, it is necessary to take into consideration the following two points.

1. Increasing or reducing body weight, depending on the kilograms, demands the equivalent period of time. In most cases, the biggest increase of body weight cannot exceed 0.5 kilo per week or in other words no more than 400 Kcal extra have to be consumed per day. At the same time, the loss of body fat (not weight) is not allowed to exceed the 0.5 to 1 kilo per week or in other words no more than 400 to 500 Kcal less have to be consumed per day, while only the athletes,

who need to lose more than 10 kilos, are allowed to lose up to 1.0 kilo fat the first two or three weeks.

2. The diet that is followed must provide all the necessary nutritional elements (ingredients), such as the correct protein quantity, fat and hydrocarbons, as well as the necessary quantities in vitamins and other nutritional elements.

We shouldn't forget that a great percentage of athletes suffer from lack of iron in the blood, while several diets that are followed do not provide the human body with the necessary vitamin quantities and several other metals (Pavlou, 1992).

1.8 Objectives

The aim of this thesis is to take advantage of a representative sample of Greek elite athletes and use multiple regression analysis to create new equations for predicting REE. For these athletes in more detail we will try to:

- Derive equations that predict the REE of elite athletes in Greece using age, height, weight, fat and sex as explanatory variables.
- Find how explanatory variables and new derived variables as fat free body mass, fat body mass, affect REE.
- Analyze the effects of interactions between all explanatory variables.
- Find differences between sexes for each explanatory variable and come up to important scientific conclusions.
- Find differences between the energy needs of the two basic body mass components (fat body mass and fat free body mass)
- Finalize the best predictive equations and compare them with other published equations.
- Present a complete solution and methodology of calculation the Total Daily Energy Expenditure of a Greek athlete.
- Provide final conclusions and critique the foreign bibliography.

It is important to note that the aim of this thesis is to predict the REE of only the high level athletes that are still active and live (and train) in Greece.