M. Peña

ANTHROPOMETRIC ASPECTS AND PHYSICAL FITNESS IN OBESE CHILDREN

Budapest, 1983
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IN OBESE CHILDREN

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CONTENTS

Foreword by O.G. Eiben 7
Acknowledgements 9
Abbreviations and symbols used in the text 10
Chapter 1: Introductory remarks 11
Chapter 2: Anthropometrical considerations in obese children 15
  2.1. Subjects and methods 20
    A) Sample No.1 and methods 20
    a) Anthropometric methods 20
    b) Statistical analysis 21
    B) Sample No.2 and methods 21
    a) Anthropometric methods 22
    b) Energy/Protein Index 22
    c) Development status 23
    d) Statistical analysis 23
  2.2. Results and comments 23
    A) Sample No.1 23
    B) Sample No.2 31
  2.3. Discussion 33
    a) Growth and development 33
    b) Anthropometric assessment 34
    c) Energy/Protein Index 36
Chapter 3: Physical fitness in obese, non-trained, and trained boys 38
  3.1. Subjects and methods 42
    a) Anthropometric methods 42
    b) Performance test 42
    c) Determinations in blood 44
    d) Statistical analysis 44
  3.2. Results and comments 45
  3.3. Discussion 52
Chapter 4: Effects of caffeine upon physical fitness in obese and non-obese boys

4.1. Subjects and methods
   a) Anthropometric assessment
   b) Performance test
   c) Statistical analysis

4.2. Results

4.3. Discussion

Chapter 5: Variations of body composition and physical fitness with different treatments

5.1. Subjects and methods
   a) Anthropometric assessment
   b) Performance test
   c) Bone age and pubertal ratings
   d) Treatments
   e) Statistical analysis

5.2. Results
   a) Anthropometric variables
   b) Physical fitness
   c) Fat absorption and mineral concentrations in serum

5.3. Discussion
   a) Anthropometric variables
   b) Physical fitness
   c) Fiber, fat, and minerals
   d) Summing-up

Chapter 6: Final comments and conclusions

Chapter 7: Summary

Chapter 8: References
Nowadays it is a common place that obesity is a public health problem in many countries. We remember the ex-general secretary of the UN, U Thant's drafting: one of the most serious problems of mankind is that a few of them eat a lot, but many people eat too less. Obesity seems to be a real problem as in Hungary as well as in Cuba. It is a good thing that Dr. Peña has chosen this problem as a theme of his study. He made a good solution with an appropriate sampling, with adequate methods—as in investigations as well as in elaboration—and with a real and modest interpretation. His book contains many good ideas and practical advices for the every-day routine, too.

The interrelationship between anthropometrical dimensions and obesity is a biological evidence. Systematic studies in this field, however, were carried out only in the last decades. From the first trivial indices (e.g. Broca's rule: "normal body weight" is equal with "height minus 100" kg) a long way led to the modern body composition investigations.

Broca's index did not take into consideration the age, on the other hand, height mostly depends on the length of the lower extremities which have a small mass. So, the weight of a tall man is relatively (proportionally) small, however, a small man's weight is relatively great.

The modern human biology—as Brozek (1965) pointed out—in studying body composition, deals with the body as a whole rather than with isolated organs and organ systems. So, the results are relevant both for medical practice and for biomedical research.

The techniques for the study of body composition are potentially useful tools. They enable us to examine human physique in terms of new dimen-
sions. But their scientific value will be determined by their contribution
to the study of problems, biological and medical.

The concern with the genesis and the significance of individual dif-
ferences in physique was present in research on body composition in vivo
from the very outset. When Matiegka in 1921 proposed his original useful
approach (The testing of physical efficiency. - Am. J. Phys. Anthropol. 4;
223-230, 1921) to the estimation of tissue masses on the basis of external
body measurements, he was anxious to place the physical anthropology of the
living man into the wider framework of human biology. It is not widely
known—and it is not stated in his above-mentioned paper—that his initial
concern was with a more adequate characterization of man's nutritional
status. But he went further and visualized the somatometric evaluation of
body composition as a component of a broad, biomedical study of man's de-
velopment, his work capacity, and his health (Brožek 1965).

It is my special pleasure that Dr. Peña's book was born in this
spirit. In the present volume it has been focused the applications of
somatometric methods to the problems of human biology. Growth and aging,
sex differences, effects of physical activity—these issues are at the very
core of human biology. The appraisal of nutritional status and the role of
physique, characterized in terms of body composition in the etiology of
disease, build a natural bridge to human biology and/or investigative
medicine and clinical practice.

I do hope that the results of Manuel Peña's research work presented
in this book will be a precious contribution to the sciences of human bio-
logy, nutrition, pediatrics, and physical education, and their practice,
too.

Ottó G. Kibben
ACKNOWLEDGEMENTS

To whom with love, advices, or help have contributed to the culmination of this work.

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I am particularly indebted to Prof. Ottó G. Elben for his valuable support and personal encouragement about the merits of this work for publication.

The author
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>BF (kg)</td>
<td>body fat in kilograms</td>
</tr>
<tr>
<td>BF (%)</td>
<td>percent of body fat</td>
</tr>
<tr>
<td>BS</td>
<td>biceps skinfold</td>
</tr>
<tr>
<td>BW</td>
<td>body weight</td>
</tr>
<tr>
<td>CS</td>
<td>calf skinfold</td>
</tr>
<tr>
<td>dB (kg)</td>
<td>variation in the body fat</td>
</tr>
<tr>
<td>dBW</td>
<td>variation in body weight</td>
</tr>
<tr>
<td>dIW/AH</td>
<td>variation of &quot;ideal&quot; weight for the actual height</td>
</tr>
<tr>
<td>dLBM (kg)</td>
<td>variation in the lean body mass</td>
</tr>
<tr>
<td>dB (BF)</td>
<td>variation in the percent of body fat</td>
</tr>
<tr>
<td>ΔG</td>
<td>variation in the blood glucose concentration</td>
</tr>
<tr>
<td>ΔL</td>
<td>variation in the blood lactate concentration</td>
</tr>
<tr>
<td>E/P</td>
<td>energy/protein index</td>
</tr>
<tr>
<td>FFA</td>
<td>free fatty acids</td>
</tr>
<tr>
<td>( f_h )</td>
<td>heart rate, beats per minute</td>
</tr>
<tr>
<td>IBP</td>
<td>International Biological Programme</td>
</tr>
<tr>
<td>IW/AH</td>
<td>&quot;ideal&quot; weight for the actual height in percent</td>
</tr>
<tr>
<td>LBM (kg)</td>
<td>lean body mass in kilograms</td>
</tr>
<tr>
<td>MAC</td>
<td>mid-arm circumference</td>
</tr>
<tr>
<td>MAMC</td>
<td>mid-arm muscle circumference</td>
</tr>
<tr>
<td>p.e.</td>
<td>physical education</td>
</tr>
<tr>
<td>PWC</td>
<td>physical working capacity</td>
</tr>
<tr>
<td>PWC _170</td>
<td>physical working capacity at a heart rate of 170 beats per minute</td>
</tr>
<tr>
<td>rpm</td>
<td>revolutions per minute</td>
</tr>
<tr>
<td>SI</td>
<td>suprailiac skinfold</td>
</tr>
<tr>
<td>SS</td>
<td>subscapular skinfold</td>
</tr>
<tr>
<td>TS</td>
<td>triceps skinfold</td>
</tr>
<tr>
<td>( \dot{V}O_2 )</td>
<td>oxygen consumption</td>
</tr>
<tr>
<td>( \dot{V}O_2/f_h )</td>
<td>oxygen pulse</td>
</tr>
<tr>
<td>( \dot{V}O_2/kg-m )</td>
<td>oxygen consumption per kilogram-meter of work done</td>
</tr>
<tr>
<td>( \dot{V}O_2/\text{max} )</td>
<td>maximal oxygen consumption</td>
</tr>
<tr>
<td>( \dot{V}O_2/\text{VO}_2 )</td>
<td>R.Q.: respiratory quotient</td>
</tr>
<tr>
<td>W</td>
<td>watt</td>
</tr>
<tr>
<td>( x \pm s.d. )</td>
<td>mean value ± standard deviation</td>
</tr>
</tbody>
</table>
Chapter 1
INTRODUCTORY REMARKS

The oldest evidence of obesity, dating from more than one hundred centuries ago, has been recognized through an archeological masterpiece: The Venus of Willendorf. Outstanding Physicians, including Hippocrates, Galen, and Celsus recorded experience and insight regarding obesity and the reduction of life-span. Nevertheless, it was not until 150 years ago that the incidence of obesity has been increasing dangerously and nowadays constitutes the most prevalent nutritional disorder in developed countries and developing ones, as well.

Obesity is characterized by an excessive quantity of adipose tissue in the body. But, how much is excessive? Brook (1978) considered obesity as indefinable since "it is simply one end of the normal spectrum of body fatness in any given population". Indeed, the cut-off points of body fatness have been settled arbitrarily, and starting from that "arbitrary" frontier many studies have been carried out. Despite this conceptual uncertainty, if only the total body mass is considered even greater difficulties arise and more confusion is attached.

This excess of fat, with rare exceptions, reflects a long term imbalance in energy intake versus energy expenditure (Committee on Nutrition, 1981). However, many factors are involved in the origin of childhood obesity. Genetics (Borjeson 1976, Brook 1978) internal, and external environmental factors interact to produce strong correlations within families (Biron et al. 1977). Whether the genetic influence is expressed in
terms of caloric intake, activity patterns, or energy utilization remains unclear (Well 1975, 1977).

In the last 20 years a large number of investigations have been devoted to the fat cell number and size in obesity. The enlargement of body fat mass is explained by an increase in the number of adipose cells (hyperplasia), or by an increase in their size (hypertrophy), or by the combination of both (Bray 1970, Knittle 1972, Brook et al. 1972).

Animal experiments have suggested that early overnutrition can induce hyperplasia of adipose tissue, and after a certain age overfeeding can only affect cell size (Knittle and Hirsch 1968, Hirsch and Hahn 1969, Lemonnier 1972). In investigations performed in humans, several authors (Brook 1972, Adebonojo 1975) considered the end of intrauterine growth and the first year of life as the sensitive period of fat cell proliferation. They stressed that hypercellularity was more frequent and severe in children who gained excessive weight during infancy than those who started their obesity later. This "adipose cell" hypothesis has been in vogue in recent years. However, subsequent reports have indicated that the matter is less simple. Häger (1976) and Brook (1979) have noted that replication may occur at any time of life, and Knittle et al. (1979) and also Häger (1976) suggested that before two years of age and during adolescence are the most important periods in the development of fat cellularity. Moreover, it has been also reported that the total number of adipose cells in children is affected by the degree of obesity irrespective of the age of onset (Wilkinson and Parker 1974, Ashwell et al. 1975, Häger 1976).

On the other hand, many data reported in the literature (Eid 1970, Taitz 1971) relating obesity in infancy with obesity in childhood or adulthood are not conclusive. Dine et al. (1979) have shown that an overweight infant has two to threefold increase in risk to become an obese child than a lean one. However, most obese infants do not become obese children or adults, as reported by Mellbin and Vuille (1976a) and Hirsch.
and Batchelor (1976). Prader et al. (1976) indicated "that only a limited and cautious prediction can be made of the amount of fat of a 15 year-old normal boy from the skinfold measurements obtained in infancy"; furthermore, Neyzi et al. (1976), Poskitt and Cole (1977) and Brook (1978) failed to demonstrate that obesity is set at early childhood.

Neither genetics (Brook 1978) nor the environment expedit ed at the first year of life are fixed quantums. Epidemiological data indicate that the increased incidence of obesity observed since the middle of the XIXth Century could be partly due to the changes of the quantitative and qualitative aspects of the diet and a greater tendency to sedentarism, among other causes (Antar et al., 1964, Robertson 1972, Cummings 1973, Burkitt et al. 1980). Therefore, acting upon the forthcoming environmental factors to which the subjects will be involved could be of help in the prevention of obesity, as was stressed recently by Vuille and Mellbin (1979). It is well known that habits of diet, exercise, and weight control are established in childhood and modified only with great difficulty in later life. This is a legitimate area for development by pediatricians and public health programmes.

It is widely accepted that obesity is a predisposing factor to a large number of disorders such as:

a) additional stress upon the cardiopulmonary and circulatory systems (Alexander et al. 1962, New and Rauh 1978),

b) it has been included as one of the risk factors for ischemic heart disease (Glueck 1980, Nora 1980),

c) alterations in lipid metabolism (Albrink and Meigs 1965, Peña et al. 1978),

d) hormonal reaction of adaptation (González 1978, Doyard et al. 1978),

e) psycho-social problems (Stunkard and Burt 1967, Brownell and Stunkard 1978), and also

f) to increase mortality (Bray 1978) among other risks, therefore the necessity of an action against the factors that contribute to its development is unquestionable.
In Cuba, as a result of the substantial changes of the socio-economic structure after the triumph of the Revolution, and the subsequent improvements of living conditions, food availability, education, and public health services have promoted a great decrease in the prevalence of deficiency diseases and a substantial reduction of the infantile mortality rate, which was 18.5/thousand live birth in 1981 (Cuba; Ministry of Public Health Annual Report, 1981). However, regional studies have shown a rise in the prevalence of obesity (Hermelo and Illnait 1975, Legón 1975). Obesity, because of its multifactorial character, requires the cooperation of multiple disciplines, and particularly the study of obesity in childhood.

The aims of this study can be summarized as follows:

- To study several anthropometric parameters in obese patients.
- To point out the importance of the body composition assessment even in the clinically evident obese subject.
- To test if there exists some correlation between the so-called Energy/Protein Index and the body fat percent, as well as with parameters which reflect physical fitness.
- To study the aerobic capacity of obese, non-obese, and specially trained boys.
- To evaluate the effect of caffeine upon the physical fitness of obese boys and to compare it with the effect on controls.
- To study the variations in body composition and physical fitness with different therapeutic regimes.
- To determine if a relative high fiber content in the diet impairs fat absorption or produces variations in the blood concentrations of several minerals.
Chapter 2

ANTHROPOMETRICAL CONSIDERATIONS IN OBSESE CHILDREN

"O that this too, too solid flesh should melt, thaw and resolve itself into a dew"

Hamlet

The most widely used anthropometric criteria in clinical practice for diagnosing malnutrition (undernutrition and overnutrition) are:

1. Measurement of the whole body mass and comparing it to the centile or to the standard weight for the chronological age. The so-called "weight for age" is an indicator that has been traditionally and mainly used in the assessment of undernutrition (Gómez et al. 1955, Waterlow 1972). A disadvantage of recording only body weight is that it does not give any information about the relative longitudinal size of the body neither of its components nor the correspondence changes with age from birth to senescence (Garn et al. 1975a).

2. A better approach to the problem may be the determination of the body weight in relation to the "ideal" or expected weight for the actual height, which has been also recommended for undernutrition assessment (Jelliffe 1966, Kerpel-Fronius 1971, Waterlow 1972). (It is important to state and well accepted that the standard weight as derived from some table does not mean "ideal" but it has been customary to use this term.) The weight for height is usually given in percent, and those individuals between 110-120 are arbitrarily considered "overweight" and over 120% as "obese". These cut-off values according to Garn et al. (1975a) have been inherited from an unknown original source. When considering the weight for the height the longitudinal size of the body is taken into account, in order to give some measure of correction.
The National Center for Health Statistics (NCHS, 1976) when fitting weight for height standards assumed the same relationship for children of different ages, a fact that has been strongly criticized (Waterlow et al. 1977). Van Wieringen (1972) demonstrated that it is fairly acceptable to pool ages 1.0 to 9.9 years but outside this range pooling introduces serious bias (Tanner 1976). Mac Laren and Read (1972, 1973, 1975) and Shukla et al. (1972) propose to compare weight for height of a child with the weight-height ratio of a standard child of the same age, in order to make it age-dependent. Later, Ounsted and Simons (1976), Waterlow et al. (1977) and Poskitt and Cole (1977) introduced indices in forms of equations. Cole, in 1979, defined weight for height as: weight for age/height for age\(^2\) introducing the power 2, but during puberty a larger power than 2 is required.

3. Other methods have been to use power type functions, Weight/Height\(^n\), starting from the point that fat distribution is independent of height but correlated with measures of adiposity. Several investigators (Quetelet 1842, Biliewicz et al. 1962, Benn 1971, Keys et al. 1972) proposed \(n = 2\), and works quite well in adults but in children the value should be 1.7 (Garrow 1981); moreover, the acceleration of the lean body mass growth in obese children (Florey 1970, Garn et al. 1974, Court et al. 1975) suggested that such derived measurements are practically invalid for certain subgroups of children (Boulton 1981). This author found a better correlation when \(n = 2\) in children over 4 years and with \(n = 1.7\) in those under 4 years old. Indeed, there seems to be little reason to believe that they are better than other predictors of fatness (Grande 1975).

4. Another practical method is the measurements of skinfold thickness as a measure of subcutaneous fat (Edwards 1950, Garn and Clark 1967). Recent studies in cadavers (Ross et al. 1981) suggest that 75 to 85% of the total adipose tissue is located externally and 15 to 25% internally. This percentage varies between individuals and with sex, and increases with
increasing fatness. The study of fatfolds approaches more closely to the actual energy status (Committee of Nutrition, 1968) and has become one of the most common methods for the assessment of body fat in clinical as well as in population studies (Garn et al. 1971). The technique is simple and has been well standardized making it possible to obtain reproducible results, comparable with other data (Grande 1975).

Due to the skewness of the distribution of skinfold thickness has been possible to establish norms for classifying obese and nonobese subjects. Seltzer and Mayer (1964, 1965) consider obese any adolescent with a triceps skinfold (TS) greater than 25 mm, on the other hand, Colley (1974) argues that many children with a TS of 20 mm appear obese, even clinically. Another mode is to consider the cut-off values of obesity to be above the 85th percentile (Garn et al. 1975b) or according to Fomon (1967) the 75th percentile, or to Stunkard et al. (1972) at the 90th percentile.

The number and sites of the skinfold to be studied is variable (Dauncy et al. 1977, Pařízková 1977, Rodríguez 1978, 1980, Mellbin and Vuille 1976a, 1976b, Boulton 1981) but it is generally accepted that it is one of the most accurate ways of measuring the child's fatness in a clinical setting.

Some authors (e.g. Garn et al. 1975a) have recommended the thoracic and abdominal skinfolds as better indices of an individual's overall fatness. Johnston et al. (1972, 1974, 1978) suggested that hereditary differences seemed to be more important for the TS and environmental for the subscapular skinfold (SS) although as yet there is no general agreement (Bogin and Mc Vean 1981).

In order to represent properly the mass of the external fat and the variation in thickness several skinfold measurements should be done (Yuhasz 1981). There is not a uniform and constant body fat distribution among individuals and the relative fat pattern remains constant over a wide range of fatness (Edwards 1951, Garn 1955, Eiben and Csébfalvi 1979).
It appears to be an individual characteristic and is not altered by different forms of physical activity or diet (Yuhasz 1977, 1980, 1981, Mueller and Wollheb 1981). Nevertheless, dealing with obesity the quantity of fat is the most important variable.

5. **Body composition**: In the last 20 years much progress has been made in the estimation of body composition, allowing one to determine with accuracy the proportion of body components. Two or four compartments-systems have been used in order to determine body fat in individuals. The two compartments are composed of lean body mass (LBM) and body fat (BF) (Behnke 1942, Forbes 1962), while the 4 compartment system is based on extracellular water, body cell mass, fat free mass, and body fat (Wang and Pierson 1976, Häger 1977). In practice the 2 compartments-system is adequate and yields enough useful information for our purpose.

Several methods are available for assessing body composition. These include uptake of fat soluble gases (radioactive krypton and cyclopropane), densitometric analysis by hydrostatic weighing, measuring the total water content of the body, and determination of $40^\text{K}$ with body counters, all these methods have been well described elsewhere, but none is suitable for routine use due to practical, ethical, and economical reasons (Peña and Peña 1977, Peña 1978).

Considering that skinfolds have been shown to be a fairly accurate approach to the measurement of subcutaneous fat at a given site, and evidence supports that the sum of several skinfold locations is a good measurement of subcutaneous fat. Since total subcutaneous fat is related to total fat it is believed that the sum of several skinfolds can be used to estimate total body fat (Lohman 1981). Hence, the correlation between skinfold thickness and density makes it possible to predict body density from skinfold measurements, and from the density formulas are available others to predict body fat: studies have been performed by many authors (Brožek et al. 1963, Durnin and
Rahaman 1967, Brook 1971, Durnin and Womersley 1974, Garrow et al. 1979). Forbes and Amirhakimi (1970), in USA, and Burmeister and Fromberg (1970), in Germany, related the data of body composition measured by whole body counting to skinfolds measurements done with a Harpenden caliper. Pařízková and Roth (1972) developed prediction equations for 2, 5, and 11 skinfolds for boys and girls using different calipers. Because of its simplicity and safety, the measurements of skinfolds are very useful to predict the body composition of children in medical practice, although the formulae to be used must be carefully selected. Recently a very important review of the numerous studies relating skinfolds to body fatness, its limitation and applicability has been done by Lohman (1981).

6. The Energy/Protein Index (E/P) has been designed as a simple indicator of nutritional status to evaluate the body components which reflect closely the relationship between adiposity and lean body mass (Amador et al. 1981a). Since E/P permits a more precise assessment of the body component variation than other widely used methods such as weight and arm circumferences, and it can be readily calculated from measures which are easily obtained (TS and mid arm circumference) it is therefore a suitable indicator for population studies and also in medical practice. This index has been correlated with different anthropometric measurements (Amador et al. 1979, 1980, 1981a), biochemical variables (Amador et al. 1976, 1977, 1982a, b) and with parameters which reflect physical fitness (Amador et al. 1981b).

The aim of this study (described in this chapter) can be summarized as follows:

a) Description of the anthropometric variables studied in our patients.

b) To point out the importance of assessing body composition even in grossly-obese patients.

c) The relationship between Energy/Protein Index and body
fat percent in obese, trained and not specially trained subjects considering this new index as a simple and a good tool in clinical practice.

2.1. SUBJECTS AND METHODS

A) Sample No.1 and Methods

This sample consists of 141 Hungarian obese children (67 girls and 74 boys), otherwise healthy, ranging in age from 10.00 to 14.99 years of decimal age. The age and sex distribution appears in Table 1.

<table>
<thead>
<tr>
<th>Age (decimal yrs.)</th>
<th>Girls N</th>
<th>Boys N</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.00-10.99</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>11.00-11.99</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>12.00-12.99</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>13.00-13.99</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>14.00-14.99</td>
<td>11</td>
<td>13</td>
</tr>
</tbody>
</table>

The decimal age was obtained from the date of birth and the date of recording, according to Tanner et al. (1969).

a) Anthropometric methods

The anthropometric measurements were taken following the procedures recommended by the International Biological Programme (IBP) (Tanner et al. 1969).

Body mass and height measurements: Body weight (BW) was measured employing a beam scale with a capacity of 0-155 kg and a precision of 0.1 kg and the stature was obtained to the nearest mm using a GPM Anthropometer (Siber-Hegner Maschinen AG, Zürich) with a range 840-2050 mm.
The ideal weight for actual height in percent (IW/AH) was calculated according to Waterlow (1972), and from the data of the growth and development study of Budapest (Eiben et al. 1971).

Skinfold thickness measurements: Fatfolds were measured with a Holtain caliper (standard pressure 10 g/mm²) on the left side of the body at 5 sites: mid-biceps (BS), triceps (TS), subscapular (SS), suprailiac (SI), and calf (CS), and recorded in duplicate by the same trained examiner. The measurements were performed according to the methodology recommended by the IBP (Tanner et al. 1969) excepting the SS that was taken at an angle of 45° to the vertical, and the SI was measured immediately above the iliac crest in the mid-axillary line (Dužnin and Womersley 1974).

Body fat percent (%BP) was estimated by the prediction equations from five skinfolds for girls and boys developed by Pařízková and Roth (1972), as follows:

\[ y = 39.024x - 43.435 \quad \text{for girls, and} \]
\[ y = 29.344x - 27.410 \quad \text{for boys} \]

where \( y \) = fat in percent of body weight
and \( x \) = log of the sum of the 5 skinfolds measurements.

Also the pubertal status of the obese children was assessed according to Tanner’s criteria (1962).

b) Statistical analysis

Means and standard deviations were calculated for all measurements. Reference values for body weight, height, and the five skinfolds were those obtained by Eiben in the cross-sectional growth study performed in Körmend, Hungary in 1978. Student’s t tests for comparisons of means were performed (Radakrishna Rao 1962, Yamane 1970).

B) Sample No.2 and Methods

Sixty Cuban boys ranging in age from 10.00 to 14.99 years were studied. Twenty of them classified as obese, since
their %BF was above 25. Another twenty were attending to a swimming training program for at least 2.5 years, and the rest of them were healthy subjects with no special training. The distribution of each of the groups was homogenated based on the chronological age, bone age by the TW2 method (Tanner et al. 1975) and pubertal status assessed by Tanner's criteria (1962).

a) Anthropometric methods

Body mass and height measurements: As described above but using a Herbert and Son's beam scale.

Mid-arm circumference [MAC]: It was measured with a fiberglass tape (Keuffel and Esser Co.) one meter long and 15 mm wide with a 10 cm blank leader, and it was taken on the mid-upper arm (mid-point distance between the acromion and the olecranon), as described by Tanner et al. (1969).

Skinfold thickness measurements: As it has been described previously. The %BF was calculated also with the regression equation for the sum of the five skinfolds (Pařížková and Roth 1972).

b) Energy/Protein Index

The Energy/Protein Index [E/P] was calculated as follows: (Amador et al. 1975). Starting from MAC and TS values in cm, the mid-arm muscle circumference (MAMC) was obtained using the formula (Jelliffe 1966):

\[ MAMC = MAC - \pi \times TS, \quad \text{where } \pi = 3.1416 \]

The transformation to a log scale of TS according to the caliper employed is as follows (Edwards et al. 1955):

\[ \text{transformed } TS = \log \text{ (reading in } 0.1 \text{ mm } - 18) \]

The E/P was calculated by the expression

\[ E/P = \frac{\text{transformed } TS}{\log MAMC} \]
c) **Development status**

The subject's radiographs of the left hand and wrist were taken and the skeletal age was calculated by the so-called TW2 method (Tanner et al. 1975). Ratings of their secondary sexual characteristics (Tanner 1962) were also completed.

d) **Statistical analysis**

Mean values and standard deviation for each of the variables studied were calculated. The differences among the three groups were tested by a one-way analysis of variance (ANOVA) with respect to each of the variables. When the differences were found to be significant pairwise comparisons were done using the Student's test. Regression line and correlation coefficient between E/P as dependent variable and %BF as independent variable were also determined within each of the groups and the three groups together (Daniel 1974, Dixon and Massey 1971).

2.2. RESULTS AND COMMENTS

A) **Sample No. 1**

The BW of obese girls and boys are shown in Fig. 1 plotted on the weight-age charts of the Budapest growth and development study (Eiben et al. 1971). Twenty-two girls and 44 boys were at or above percentile 97; thirty-five girls and twenty-six boys were between the 90th and 97th percentiles, and ten girls and four boys were between the 75th and 90th percentiles. Four children of the latter group, although did not achieve the 90th percentile of weight were severely obese since they also exhibited the smallest heights and higher %BF than others located in a higher percentile; therefore, considering weight for age alone is not possible in all cases to quantify the magnitude of obesity.

The distribution of the height in both sexes are represented in Fig. 2 and the number of subjects distributed according to the range of percentiles appears in Table 2.
Fig. 1 Body weight distribution in obese girls and boys

Fig. 2 Stature distribution in obese girls and boys
Table 2
Distribution of obese girls and boys according to the range height percentiles

<table>
<thead>
<tr>
<th>Percentile</th>
<th>Girls N</th>
<th>Boys N</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 90</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>89 - 75</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>74 - 50</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>49 - 25</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>&lt; 25</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

The stature of 43 girls and 37 boys were at or above the 75th percentile--as reported by many authors--, but the proportion of "tall" children is much lower from 13 years old on. Otherwise, there was no sign of early appearance of secondary sexual characteristics, nor an advanced bone age in the majority of cases.

On examination of Fig. 3 in which the mean values were compared with those obtained by Eiben in the Körmen study in 1978, permits us to see that at all ages the obese boys' height means were higher than that of the controls although from 13 years on the level of significance decreased. Regarding the girls, they were significantly taller just up to age 14 in which no significant difference was observed, similar results were reported by Larom et al. (1978).

Figure 4 compares five skinfolds thicknesses of controls and obese girls and boys at different ages. The fat distribution in both sexes was similar to that obtained by Pařízková (1977), although the number of the sample is too small to permit detailed statistical analysis by age and sex. When comparing the obese children with the controls significant differences were found in all cases p < 0.001. The greatest deviation from the standard value was obtained in the subscapular skinfold.
Fig. 3 Stature of obese and non-obese children at different ages
Fig. 4 Skinfold thicknesses of obese and non-obese children
Table 3
Paired comparison of obese children

<table>
<thead>
<tr>
<th>Patient</th>
<th>Height (cm)</th>
<th>Body weight (kg)</th>
<th>IW/AH (percent)</th>
<th>Body fat (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>148.8</td>
<td>55.3</td>
<td>133.96</td>
<td>36.24</td>
</tr>
<tr>
<td>2 girl</td>
<td>149.0</td>
<td>55.3</td>
<td>133.96</td>
<td>33.03</td>
</tr>
<tr>
<td>3 girl</td>
<td>146.2</td>
<td>50.1</td>
<td>135.26</td>
<td>31.83</td>
</tr>
<tr>
<td>4</td>
<td>145.2</td>
<td>49.7</td>
<td>134.18</td>
<td>33.43</td>
</tr>
<tr>
<td>5 boy</td>
<td>158.4</td>
<td>87.5</td>
<td>178.6</td>
<td>36.62</td>
</tr>
<tr>
<td>6</td>
<td>158.0</td>
<td>87.4</td>
<td>178.6</td>
<td>35.49</td>
</tr>
<tr>
<td>7 boy</td>
<td>138.5</td>
<td>49.5</td>
<td>153.4</td>
<td>28.32</td>
</tr>
<tr>
<td>8</td>
<td>138.0</td>
<td>49.5</td>
<td>153.4</td>
<td>32.12</td>
</tr>
<tr>
<td>9 boy</td>
<td>145.4</td>
<td>52.5</td>
<td>131.91</td>
<td>32.33</td>
</tr>
<tr>
<td>10</td>
<td>145.4</td>
<td>57.5</td>
<td>144.22</td>
<td>31.10</td>
</tr>
<tr>
<td>11 boy</td>
<td>153.8</td>
<td>62.0</td>
<td>140.75</td>
<td>28.27</td>
</tr>
<tr>
<td>12</td>
<td>153.8</td>
<td>61.4</td>
<td>139.48</td>
<td>31.67</td>
</tr>
<tr>
<td>13 boy</td>
<td>168.0</td>
<td>79.2</td>
<td>145.97</td>
<td>26.46</td>
</tr>
<tr>
<td>14</td>
<td>167.8</td>
<td>79.6</td>
<td>146.65</td>
<td>34.58</td>
</tr>
</tbody>
</table>

In Table 3 several obese children were arranged in pairs to compare their body weight, their IW/AH, and the %BF. Evident discrepancies were found between the IW/AH and the %BF as could be seen: Patient 1 and 2 had practically the same stature, their BW and IW/AH values were similar in both of them respectively; thus, according to this they had the same degree of overweight. Yet, when the %BF was calculated to each of them, Patient 1 was found to have a higher figure than the other one (see also Fig. 5). A similar situation happened with pairs 5-6 and 7-8, in the latter a difference of 3.8% of the body fat was seen with no differences in IW/AH.

Although it is true generally that a relative high weight expresses an increase in fat, in some cases it is due to an in-
Fig. 5  Body weight stature and %BF in two obese patients

Fig. 6  Body weight stature and %BF in two obese patients
Fig. 7  Body weight stature and %BF in two obese patients
Fig. 14 Correlation between body fat percent and log(PWC/BW).

Fig. 15 Oxygen consumption of different standard work loads.
**Fig. 12** Maximal oxygen consumption of obese, non-obese, and specially trained adolescents

**Fig. 13** Relative values of maximal oxygen consumption of obese, non-obese, and specially trained adolescents
Fig. 10  PWC$_{170}$ of obese, non-obese, and specially trained adolescents

Fig. 11  Relative values of PWC$_{170}$ of obese, non-obese, and specially trained adolescents
variable was performed. The relationship between oxygen consumption and work rate for obese and non-obese boys during the standard exercise were calculated.

In order to establish the degree of association between E/P and parameters which reflect physical fitness we also calculated the regression lines and the correlation coefficient between E/P as dependent variable and PWC_{170}, PWC_{170}/BW, and PWC_{170}/LBM as independent ones (Radakrishna Rao 1962, Yamane 1970).

3.2. RESULTS AND COMMENTS

Figure 10 shows the means and the standard deviation of the PWC_{170} and Figure 11 the PWC_{170} related to BW and the LBM of the three groups. The swimmers, as it could be expected, achieved the highest figures; on the other hand, no differences were obtained between the obese and non-trained boys regarding PWC_{170} scores, but when comparing their relative values the obese yielded lower results.

Figure 12 shows the \( \dot{V}O_{2\text{max}} \) and Figure 13 the relative values for each of the groups. The controls, with similar values to those reported by Suzuki et al. (1978), and Ikai and Kitagawa (1972), and the obese practically raised to similar figures of \( \dot{V}O_{2\text{max}} \), however, respecting relative values the obese revealed the poorest results. Since the swimmers were able to perform more work, they exhibited the highest \( \dot{V}O_{2\text{max}} \) figures comparable to those obtained by Sprynarová et al. (1978) in a similar sample. The correlation between %BF and the logarithm of PWC_{170}/BW appears in Figure 14 showing that the higher the %BF is the lower the fitness, confirming once more the disadvantage of overfatness in physical performance.

An attempt was undertaken to determine how much oxygen the boys consumed per kg-m of work done during one of the submaximal workloads. The establishment of a steady state was demonstrated for obtaining an accurate measurement (Margaria
as the PWC$_{170}$ for the individual, PWC$_{170}$ and VO$_{2\max}$ have been recorded in absolute values as well as divided by the body weight and lean body mass.

Another test was given to 4 controls and 4 obese boys between 11 and 12 years of age. It consisted of three workloads of small amount: 20, 40, and 60 Watts, respectively. The duration of each load was 5 minutes and 1 minute of rest was given between them. Every minute the VO$_2$, VCO$_2$, f$_h$, and the actual work performed were registered and recorded by the equipment.

c) Determinations in Blood

A venous blood sample was drawn from each subject before and immediately after the performance test, in order to determine the concentration of glucose, by a glucose-oxidase method with an AC-60 automatic analyzer (González 1977) and lactate using an enzymatic method (Boehringer-Mannheim). All the determinations were made in duplicate.

The difference between the concentration obtained after and before the test was calculated for each individual and recorded as $\Delta G$ for the glucose variation and $\Delta L$ for the lactate variation.

d) Statistical Analysis

For each of the variables studied the mean values and standard deviations were calculated. Differences among the three groups were tested by a one-way ANOVA, and when it was significant binary comparisons were done according to the Student's test. Regarding the individual variations for blood glucose and lactate, $\Delta G$ and $\Delta L$ respectively, were assessed by a Student's t test for paired data in each of the groups, the differences of the means of these variations among the groups were also tested by a one-way ANOVA, and for the binary comparisons a t test was done.

Pearson's correlation coefficient and the linear regression equation between the logarithmic transformation of PWC$_{170}$ (log PWC$_{170}$) as dependent variable and the %BF as independent
avoid the use of drugs and food immediately before the test; as have been suggested by Jones and Haddon (1973).

On the day of the test, the subjects reported, at least one hour earlier in order to observe their companions being tested and also enabled them to know the general details of the procedure. All of them established friendly competition and enhanced the likelihood of attaining maximum effort. The room was air-conditioned in order to provide a relative constant 17°C considered by Rowell et al. (1964) as the optimal environmental temperature.

A Mijnhardt electronic cycle ergometer was used with parabolic and hyperbolic systems, hence the variation of pedalling frequency did not affect the power output. The cycle saddle was adjusted to a height that produced a knee joint angle of 150°. This angle allows for maximum pedalling efficiency (Klimt and Voigt 1971). The subjects were coupled to a computerized Mijnhardt Ergo-analyzer which registered every minute the oxygen consumption (\(\dot{V}O_2\)), the ratio \(\dot{V}CO_2/\dot{V}O_2\)--respiratory quotient--, the heart rate (\(f_h\)), the oxygen pulse (\(\dot{V}O_2/f_h\)), and the actual amount of work done, all these variables were recorded until the subject appraised the maximum effort.

The ISF exercise protocol (Seliger 1970), consisted of three sub-maximal workloads (1.0-1.5-2.0 Watt/kg) with one minute of rest between them. After the third period and two minutes of rest, started the maximum loading which was opened with 1 minute load of 2.5 Watt/kg and increased every minute by 15 W until the maximum effort was reached, following the criteria proposed by Shephard (1978). The pedalling rate was about 60 rpm, considered the most efficient (Mellerowicz 1966, Bannister and Jackson 1967, Hermansen and Saltin 1969).

The Physical Working Capacity (PWC) was calculated by a regression line obtained through a correlation between work rates in Watt and the heart rates at each of the submaximal workload in the steady state (Seliger 1970, 1975). The PWC that could produce a heart frequency of 170/min was recorded
3.1. SUBJECTS AND METHODS

A selected sample of sixty Cuban boys from 10.00 to 14.99 years of age were studied. They formed three homogeneous groups respecting chronological age, bone age by the TW-2 (Tanner et al. 1975), and sexual development according to Tanner's criteria (1962).

- Non-trained group: Twenty healthy boys, whose \( BF \) was between 14 and 20, regarded as controls.

- Obese: Twenty obese boys, otherwise healthy, whose \( BF \) was above 25.

- Trained group: Twenty swimmers who attained to systematically trained for at least 2.5 years -- 11 sessions per week -- whose body fat percent was in the same range as the non-trained ones.

a) Anthropometric methods

The general details of the methodology employed, instruments and apparatuses were the same referred to in Sample No.2 in Chapter 2.

The sequence of measurements was: Height, Body weight, Mid-arm circumference, Triceps skinfold, Biceps skinfold, Subscapular skinfold, Suprailiac skinfold, and Calf skinfold.

The \( BF \) was calculated using Pařízková and Roth's (1972) prediction equation from 5 skinfolds as described in Chapter 2.

The body fat mass expressed in kilograms (BFkg) was obtained from the \( BF \) and the BW, and the lean body mass (LBM kg) was obtained by subtracting the BFkg from the BW.

E/P index was also calculated as referred in Chapter 2.

b) Performance Test:

We advised every subject to avoid exposure to extremes of climate and physical activity on the day preceding the examination, to ensure adequate sleep on the preceding night and to
Although the effect of undernutrition upon fitness has not been deeply studied, there exists evidence that the working capacity is affected (Viteri 1974, Satyanarayana et al. 1978, Shephard 1978). Furthermore, it has been reported that maximal working capacity is improved when undernourished individuals are in recovery (Spurr et al. 1974).

On the other hand, obesity means a handicap from the functional point of view, especially in aerobic exercise (Pařízková 1978). The obese subjects have been characterized as poor performers with a low aerobic capacity. Vamberová et al. (1971) found that when obese and lean individuals performed the same work, the obese consumed more oxygen than the non-obese. Pařízková (1977) measured the VO_{2}max during maximum load and detected no differences between normal and obese boys, but the relative values of VO_{2}max were poorer in the obese while on the other hand, the lean were able to perform significantly more work (Šprynarova and Pařízková 1962, 1965). These authors concluded that obese children exhibited a reduced economy of work. Furthermore, when the obese subjects reduced their body fat an improvement in physical performance was obtained (Wells et al. 1962, Jokl 1964, Pařízková 1972, Björntorp 1977).

It has been suggested by several authors (Apfelbaum 1971, Goldman 1975) that the work efficiency of the obese is reduced, an assertion that is controvertible.

The purpose of our investigation were:

- To study the physical fitness of obese, non-obese, and boys submitted to a regular training.

- To assess the aerobic capacity during a maximal load to each of the groups and the variations of blood glucose and lactate.

- To evaluate if the poor performance of the obese boys is due to an alteration of the work efficiency or due to the excess of fat.

- To study the relation between Energy/Protein Index and physical fitness.
crease in muscle mass. The quantitative information offered by the IW/AH is not always proportional to the actual fat mass and in some cases it is paradoxical. For example, Patient 9 exhibited a lower body weight and IW/AH than the Patient 10—both with the same height—but he had a higher %BF; hence, the "lighter" was more obese than the heavier one (Fig. 6). The same occurred with pairs 3-4 and 11-12 (Fig. 7). In other words, in these cases those who had a slightly higher IW/AH were less obese than their peers.

Another case which shows this discrepancy is Patient 13, who practices wrestling, he has a high IW/AH (145.97%) and 26.46% BF when we matched him with Patient 14 with quite similar IW/AH, the difference in %BF between them was more than 8. This confirms that overweight and obesity cannot be regarded as synonyms, because muscular development, body build, and body composition are all to be taken into consideration.

B) Sample No. 2

The means and standard deviations for E/P and %BF of each of the groups studied are shown in Fig. 8. ANOVA shows highly significant F values. Binary comparisons between groups also yielded significant differences (p<0.001) excepting between trained and non-trained that was p<0.025.

For each group of boys (trained, non-trained, and obese) and for the whole sample a correlation study between %BF and E/P is given in Fig. 9. A highly significant coefficient was obtained in each case which demonstrates a close relationship between the index and adiposity. It is important to stress that E/P reflects not only the degree of adiposity but also a relationship between adiposity and lean body mass (Amador et al. 1981a). In the groups of subjects studied, differences in the development of both components could be expected as it has been reported earlier that in obese subjects there is not only "overfatness" but also an increase of the lean body mass (Forbes 1964, Womersley et al. 1976); on the other hand, in
Fig. 8 E/P index and body fat percent in obese, non-trained, and trained boys

Fig. 9 Correlation between body fat percent and E/P index
trained boys it is obvious that muscle mass should be increased; thus, the relation between both components should also be different.

2.3. DISCUSSION

a) Growth and development

Pařížková (1977) referred to "some rejected problems pertaining to an uneven development of body composition and body weight" of groups of obese children. She also found marked somatic differences besides the increased body weight and body fat.

Bruch in 1939, Quaade (1955), and Wolff (1955) were among the first investigators who indicated an association between "tallness" and "fatness". Forbes (1964) identified a subgroup of obese subjects with an early onset of overweight characterizing them as statural and skeletally advanced, early maturer and quite refractory to slimming programs. Brook (1973) also noted that the earlier the onset of obesity the greater the reported excess in height. On the other hand, Frisch (1974), and Frisch and Revelle (1969, 1974) hypothesized that the mean weight of girls at the time of menarche was 47 kg, the so-called "critical weight", recently, they stressed that the percentage of fat in the mature human female may influence reproductive ability as an extragonadal source of estrogen or influencing its metabolism (Frisch 1980a, 1980b). Examinations carried out so far have yielded a relationship between maturation rate and physique, there is a tendency that the endomorphic girls used to mature earlier (Kralj-Čerček 1956, Tanner 1962, Bodzsár 1980). Indeed, the age of onset and the course of the pubertal events are influenced by many factors such as heredity, ethnic origin, climatic conditions, and nutrition among others. Many authors have found a relative acceleration of maturity related to overweight (Wolff 1955, Garn et al. 1975a, Zaccharias et al. 1970, Foster et al. 1977). In our sample we did not detect this feature either in girls or in
boys, coinciding with other previous studies in larger samples (Johnston et al. 1975, Laron et al. 1978, Mach and Johnston 1979). So far, the general implication between fatness and early maturation is rather controversial.

Garn et al. (1975b) in the Ten-State Nutrition Survey reported that the obese boys and girls were taller than their lean age peers from at least the second year on through 12 years, and also the size of the skeletal components is greater with respect to length as to radiogrammetrically determined widths. Pařízková (1977) also found a greater robusticity according to the bicondylar femur figures and a greater ilioocrystal diameter. Boulton (1981) observed a positive association between skinfold thickness and height excepting girls aged 2, 4, and over 14 years old and boys of 4, but the correlation coefficients were rather small.

According to our results 43 girls and 37 of the boys studied exhibited heights at or above the 75th percentile, a fact more evident in the younger of the sample, but this finding does not allow us to state that obesity promotes high stature. Some caution must be exercised in interpreting it. We agree with Johnston and Mack (1980a) on the question: whether growing children are more prone to obesity or whether a positive nutritional balance accelerates the processes of physical development, remaining still unanswered. It seems to be that the excessive weight gain in infancy is more related to increased stature than fatness itself during adolescence (Forbes 1964, Brook 1973, Hueneman 1974, Johnson and Mack 1980b). Undoubtedly genetics, nutrition, emotional and ecological factors influence the rate of growth and the final height achieved (Tanner 1962, Widowson and Mc Cance 1974, Stini 1980, Prokopec 1980) but the causal and the extent of the relationship between the factors remain uncelar.

b) **Anthropometric assessment**

It is of great importance to distinguish between the in-
dividual assessment of the nutritional status and the assessment in populations or sub-populations. Habicht (1980) pointed out that the main fact is the choice of indicators according to the type of malnutrition, its degree, and time of evolution. Previous to any study it is necessary to precise the purpose of it. Applying schematically the same pattern to every condition the probability of misdiagnosing could be high (Amador et al. 1982a).

The limitation of using body weight and height in assessing obesity is well recognized. As Jean Mayer phrases it (Palmer and Ekvall 1978): "Visual observation by an experienced observer is a more reliable method than the automatic appliance of the weight-height tables". In infants the relative weight for height is an acceptable measurement of infant fatness in wide samples (Johnston and Hack 1978, 1980a, 1980b), although there is a disagreement in about 10% of the cases. Lesser et al. (1971) studied the relationship of body fat to relative weight for height and for young men and women found it to agree fairly well, but in older groups the relationship breaks down. Parnell (1977) considered that in the slightly overweight—marginal cases—it is important to distinguish between adiposity and muscularity but in the clinically obese this problem does not arise. As a matter of fact, we consider that in the grossly obese the diagnosis even could be done clinically. Otherwise, many authors (Seltzer and Mayer 1964, Fox 1974, Bray et al. 1972, Garn et al. 1975a, Peña et al. 1979b) stated that there is not any other alternative but to diagnose obesity as measuring fatness. Furthermore, the discrepancies presented by us show that not only from the diagnostic point of view it is important to measure body fat. This permits a better characterization of the patient and assures a more reliable follow-up. For example, to assess accurately the influence of dietary restriction upon body composition, to examine with more precision fitness parameters in which the results must be referred to body weight or lean body mass (Shephard 1978), and when physical exercise is involved
in the treatment the variation in body fat is more relevant than the variation in whole body mass (Peña et al. 1979b, 1980). Unfortunately, the determination of body fat is seldom done even in specialized centers limiting, therefore, the comparison and interpretation of results dealing with obese individuals.

A controversial aspect is the application of predictive equations from skinfold measurements from different populations (Johnston 1981). There is some evidence that LBM or BF equations may be slightly more valid than density equations when applied to other populations--e.g. obese subjects, ethnic origins, different environment--(Jackson and Pollock 1978). Due to the linear relationship between fat weight and the sum of skinfolds as compared to the quadratic relation between density and skinfolds, fat weight appears to be more predictable (Chien et al. 1975, Jackson and Pollock 1977, Lohman 1981). That is the reason why we use those equations developed by Pařízková and Roth (1972), since unfortunately, no prediction equations are still available from these populations studied by us. Notwithstanding, the information yielded by these equations is much more accurate than the other methods used in clinical practice.

c) Energy/Protein Index

This index has been developed in our department of Nutrition by Amador et al. (1975, 1979) and has demonstrated its usefulness as an indicator of the nutritional status.

The significant correlations between E/P and several anthropometric variables have been reported in previous studies. Close relationship between E/P and anthropometric measurements regarding whole body mass, body weight, arm area and arm circumference have been obtained (Amador et al. 1980), but the highest correlations were those with measurements which reflect in some way the degree of adiposity with respect to fat in the middle arm area, and the first component of somato-
type (Amador et al. 1979). The association of E/P with criteria commonly used to define obesity has also been described (Amador et al. 1981a). Our findings of a significant correlation between E/P and %BF are consistent with these previous assumptions, and confirm the assertion that it can be used as a measure of adiposity.

It is important to point out that E/P besides reflecting the degree of adiposity gives also information about the relationship between adiposity and lean body mass, explaining the significant differences between all the subgroups found. We do not pretend to substitute the %BF by the E/P but to denote that it may be a helpful tool in clinical practice, and it could be used alone or in combination with other indicators, since it is simple to calculate and its ability for diagnosing "marginal cases" has already been proved (Amador et al. 1981a).
Chapter 3

PHYSICAL FITNESS IN OBESE, NON-TRAINED, AND TRAINED BOYS

"Make less thy body hence, and more thy grace; leave gormandising; know the grave doth gape for thee thrice wider than for other men."

King Henry V (to Falstaff)

The capacity of response to exercise has become a very important tool for a comprehensive evaluation of health or its impairment. Malina (1980) has stated that any consideration of growth and development should concern itself with physical performance and those factors that influence it. Moreover, the exercise tests may give useful information of the extent of the abnormality or reveal how a subject reacts to work despite his disability (Godfrey 1974).

Physical performance capacity is commonly divided into energy liberation, neuromuscular function, metabolic and biochemical events, and psychological factor (Hermansen 1979, Pařízková 1980). Energy liberation, considered as basic, has in a broad sense two components: the aerobic processes and the anaerobic processes. Many authors agree that the most important determinant of endurance fitness is the aerobic power or maximal oxygen uptake ($\tilde{V}O_{2\text{max}}$) (Malina 1980, Åstrand 1972, Shephard 1978, Hermansen 1979, Wolański 1980). This parameter may be measured directly, and for this purpose several protocols have been designed: or it can be measured indirectly by extrapolations of the heart rate ($f_h$) or oxygen consumption at submaximal work loads (Andersen et al. 1971, Davies 1968, Shephard 1978). Nevertheless, certain difficulties exist regarding methodological and technical aspects, limiting, therefore, the possibilities of comparison between different studies.
The main physiological event during exercise is the contraction of skeletal muscle. This event requires the participation of many enzymes to promote the conversion of chemically bound energy (phosphagen compounds) into mechanical energy. Since the source of this chemical energy for maintaining exercise is very scarce the replenishment of this compound should take place via aerobic or anaerobic pathways. The rate of regeneration via oxidative phosphorilation is limited by the \( \dot{V}_O_{2\max} \) and this \( \dot{V}_O_{2\max} \) is restricted primarily by the ability of the respiratory and cardiovascular systems to transport oxygen from the atmosphere to the muscle. Hence, the \( \dot{V}_O_{2\max} \) is determined by the cardiac output, and the oxygen difference between the arterial and venous blood (Hermansen 1979) and that is why it is generally considered the best single indicator of cardiorespiratory fitness or the efficiency of the oxygen transport system (Shephard et al. 1968, 1978, 1980, Malina 1980).

Multiple factors are involved in the physical fitness of an individual: hereditary (Cotes and Davies 1969, Klissouras 1971, 1973) physical organic, environmental (Brouwers and Lavenne 1969), and behavioral components (Blischke and Quell 1980). More recently, Renson et al. (1980) described also social determinants, but it seems to be that individual endowment and habitual physical activity are the most important ones (Dedoyard and Ghesquière 1980).

Since there is a great amount of information about the effects of habitual physical activity (e.g. training) upon the organism we should try to summarize as follows:

that adequate physical activity enhances the development of the functional capacity during puberty. Positive changes in central circulation have been noted by Ekblom (1960, 1971) and Saltin et al. (1976) as well as in the muscle blood flow (Koch 1974, 1978). Increase in heart volume, vital capacity and the heart rate response were observed by Rous (1980), Gatch and Byrd (1979), Shephard et al. (1978) and Reindell et al. (1960) among others. In a recent longitudinal study, Placheta (1980) concluded that in a group of children with controlled physical training during three years their fitness values exceeded the natural increments of untrained boys by ten to forty percent; moreover, Saltin et al. (1969) and Pollock (1973) observed an increase of 25% of the $\dot{V}O_{2max}$ in sedentary subjects with long term training.

- An increase in enzyme concentrations within the muscle fiber have been demonstrated by Morgan et al. (1971), Poortmans (1972), Gollnick et al. (1973), Holloszy (1973), Howald (1975) and increments of the size and density of the mitochondriae have also been reported (Holloszy 1967, Kiessling et al. 1971).

- Simmons and Shephard (1971) found that training facilitates sweating and therefore thermal regulation during exercise promoting a deviation of blood from the skin to the working muscle (Nadel 1980).

- Also motor abilities and skills are developed with habitual physical activity (Placheta 1980, Matsuura 1980).

Besides these morpho-functional effects, must be mentioned the positive influences upon psychologic development and the biosocial environment.

The level of nutrition is one of the most important environmental factors able to modify physical fitness (Åstrand 1972, 1973, Pařízková 1977, Rogozkin (1978) underlined that adequate nutrition increases working capacity, and also described the basic principles to be applied in nutritional plans for sportsmen.
Although the effect of undernutrition upon fitness has not been deeply studied, there exists evidence that the working capacity is affected (Viteri 1974, Satyanarayana et al. 1978, Shephard 1978). Furthermore, it has been reported that maximal working capacity is improved when undernourished individuals are in recovery (Spurr et al. 1974).

On the other hand, obesity means a handicap from the functional point of view, especially in aerobic exercise (Pařízková 1978). The obese subjects have been characterized as poor performers with a low aerobic capacity. Vamberová et al. (1971) found that when obese and lean individuals performed the same work, the obese consumed more oxygen than the non-obese. Pařízková (1977) measured the $\dot{V}O_{2\max}$ during maximum load and detected no differences between normal and obese boys, but the relative values of $\dot{V}O_{2\max}$ were poorer in the obese while on the other hand, the lean were able to perform significantly more work (Šprynarová and Pařízková 1962, 1965). These authors concluded that obese children exhibited a reduced economy of work. Furthermore, when the obese subjects reduced their body fat an improvement in physical performance was obtained (Wells et al. 1962, Jokl 1964, Pařízková 1972, Björntorp 1977).

It has been suggested by several authors (Apfelbaum 1971, Goldman 1975) that the work efficiency of the obese is reduced, an assertion that is controvertible.

The purpose of our investigation were:

- To study the physical fitness of obese, non-obese, and boys submitted to a regular training.

- To assess the aerobic capacity during a maximal load to each of the groups and the variations of blood glucose and lactate.

- To evaluate if the poor performance of the obese boys is due to an alteration of the work efficiency or due to the excess of fat.

- To study the relation between Energy/Protein Index and physical fitness.
3.1. SUBJECTS AND METHODS

A selected sample of sixty Cuban boys from 10.00 to 14.99 years of age were studied. They formed three homogeneous groups respecting chronological age, bone age by the TW-2 (Tanner et al. 1975), and sexual development according to Tanner's criteria (1962).

- **Non-trained group**: Twenty healthy boys, whose %BF was between 14 and 20, regarded as controls.

- **Obese**: Twenty obese boys, otherwise healthy, whose %BF was above 25.

- **Trained group**: Twenty swimmers who attained to systematically trained for at least 2.5 years--11 sessions per week--whose body fat percent was in the same range as the non-trained ones.

a) **Anthropometric methods**

The general details of the methodology employed, instruments and apparatuses were the same referred to in Sample No.2 in Chapter 2.

The sequence of measurements was: Height, Body weight, Mid-arm circumference, Triceps skinfold, Biceps skinfold, Sub-scapular skinfold, Suprailiac skinfold, and Calf skinfold.

The %BF was calculated using Pařízková and Roth's (1972) prediction equation from 5 skinfolds as described in Chapter 2.

The body fat mass expressed in kilograms (BFkg) was obtained from the %BF and the BW, and the lean body mass (LM kg) was obtained by subtracting the BFkg from the BW.

E/P index was also calculated as referred in Chapter 2.

b) **Performance Test**

We advised every subject to avoid exposure to extremes of climate and physical activity on the day preceding the examination, to ensure adequate sleep on the preceding night and to
avoid the use of drugs and food immediately before the test; as have been suggested by Jones and Haddon (1973).

On the day of the test, the subjects reported, at least one hour earlier in order to observe their companions being tested and also enabled them to know the general details of the procedure. All of them established friendly competition and enhanced the likelihood of attaining maximum effort. The room was air-conditioned in order to provide a relative constant 17°C considered by Rowell et al. (1964) as the optimal environmental temperature.

A Mijnhardt electronic cycle ergometer was used with parabolic and hyperbolic systems, hence the variation of pedalling frequency did not affect the power output. The cycle saddle was adjusted to a height that produced a knee joint angle of 150°. This angle allows for maximum pedalling efficiency (Klimt and Voigt 1971). The subjects were coupled to a computerized Mijnhardt Ergo-analyzer which registered every minute the oxygen consumption (\( \dot{V}O_2 \)), the ratio \( \dot{V}CO_2/\dot{V}O_2 \)--respiratory quotient---, the heart rate \( (f_h) \), the oxygen pulse \( (\dot{V}O_2/f_h) \), and the actual amount of work done, all these variables were recorded until the subject appraised the maximum effort.

The IBP exercise protocol (Seliger 1970), consisted of three sub-maximal workloads (1.0-1.5-2.0 Watt/kg) with one minute of rest between them. After the third period and two minutes of rest, started the maximum loading which was opened with 1 minute load of 2.5 Watt/kg and increased every minute by 15 W until the maximum effort was reached, following the criteria proposed by Shephard (1978). The pedalling rate was about 60 rpm, considered the most efficient (Mellerowicz 1966, Bannister and Jackson 1967, Hermansen and Saltin 1969).

The Physical Working Capacity (PWC) was calculated by a regression line obtained through a correlation between work rates in Watt and the heart rates at each of the submaximal workload in the steady state (Seliger 1970, 1975). The PWC that could produce a heart frequency of 170/min was recorded
as the PWC$_{170}$ for the individual, PWC$_{170}$ and $V_{O_{2max}}$ have been recorded in absolute values as well as divided by the body weight and lean body mass.

Another test was given to 4 controls and 4 obese boys between 11 and 12 years of age. It consisted of three workloads of small amount: 20, 40, and 60 Watts, respectively. The duration of each load was 5 minutes and 1 minute of rest was given between them. Every minute the $V_{O_{2}}$, $V_{CO_{2}}$, $f_{h}$, and the actual work performed were registered and recorded by the equipment.

c) Determinations in Blood

A venous blood sample was drawn from each subject before and immediately after the performance test, in order to determine the concentration of glucose, by a glucose-oxidase method with an AC-60 automatic analyzer (González 1977) and lactate using an enzymatic method (Boehringer-Mannheim). All the determinations were made in duplicate.

The difference between the concentration obtained after and before the test was calculated for each individual and recorded as $\Delta G$ for the glucose variation and $\Delta L$ for the lactate variation.

d) Statistical Analysis

For each of the variables studied the mean values and standard deviations were calculated. Differences among the three groups were tested by a one-way ANOVA, and when it was significant binary comparisons were done according to the Student's test. Regarding the individual variations for blood glucose and lactate, $\Delta G$ and $\Delta L$ respectively, were assessed by a Student's t test for paired data in each of the groups, the differences of the means of these variations among the groups were also tested by a one-way ANOVA, and for the binary comparisons a t test was done.

Pearson's correlation coefficient and the linear regression equation between the logarithmic transformation of PWC$_{170}$ ($\log \text{PWC}_{170}$) as dependent variable and the $\text{BF}$ as independent
variable was performed. The relationship between oxygen consumption and work rate for obese and non-obese boys during the standard exercise were calculated.

In order to establish the degree of association between E/P and parameters which reflect physical fitness we also calculated the regression lines and the correlation coefficient between E/P as dependent variable and PWC\textsubscript{170}, PWC\textsubscript{170}/BW, and PWC\textsubscript{170}/LBM as independent ones (Radakrishna Rao 1962, Yamane 1970).

3.2. RESULTS AND COMMENTS

Figure 10 shows the means and the standard deviation of the PWC\textsubscript{170} and Figure 11 the PWC\textsubscript{170} related to BW and the LBM of the three groups. The swimmers, as it could be expected, achieved the highest figures; on the other hand, no differences were obtained between the obese and non-trained boys regarding PWC\textsubscript{170} scores, but when comparing their relative values the obese yielded lower results.

Figure 12 shows the \( \dot{V}O_{\text{2max}} \) and Figure 13 the relative values for each of the groups. The controls, with similar values to those reported by Suzuki et al. (1978), and Ikai and Kitagawa (1972), and the obese practically raised to similar figures of \( \dot{V}O_{\text{2max}} \); however, respecting relative values the obese revealed the poorest results. Since the swimmers were able to perform more work, they exhibited the highest \( \dot{V}O_{\text{2max}} \) figures comparable to those obtained by Šprynarová et al. (1978) in a similar sample. The correlation between \%BF and the logarithm of PWC\textsubscript{170}/BW appears in Figure 14 showing that the higher the \%BF is the lower the fitness, confirming once more the disadvantage of overfatness in physical performance.

An attempt was undertaken to determine how much oxygen the boys consumed per kg-m of work done during one of the sub-maximal workloads. The establishment of a steady state was demonstrated for obtaining an accurate measurement (Margaria
Fig. 10 PWC<sub>170</sub> of obese, non-obese, and specially trained adolescents

Fig. 11 Relative values of PWC<sub>170</sub> of obese, non-obese, and specially trained adolescents
Fig. 12 Maximal oxygen consumption of obese, non-obese, and specially trained adolescents

Fig. 13 Relative values of maximal oxygen consumption of obese, non-obese, and specially trained adolescents
Fig. 14 Correlation between body fat percent and log(PWC/BW)

Fig. 15 Oxygen consumption of different standard work loads
et al. 1985). The swimmers and the controls did not differ in their results, but the obese significantly consumed more oxygen per unit of work than the other groups, as can be seen in Table 4, a result that agrees with previous reports (Vamberová et al. 1971, Párizková 1977). This finding induced us to assess in 4 obese and 4 controls the oxygen uptake at three submaximal loads of small magnitude, in order to ensure sufficient exercise points of aerobic work (Whipp and Wasserman 1972) and to know the rate of variation of the VO₂. For this purpose high rates of work were avoided (Åstrand and Saltin 1961, Whipp and Wasserman 1970, Wasserman et al. 1967, Whipp 1975) since if a steady state is not reached the VO₂ measurements do not represent the oxygen cost of a given work rate (Åstrand and Saltin 1961). The regression line for each group had practically the same slope (Figure 15) and only differed in the intercept what could be explained by an extraload which remains constant in each of the three stages.

Table 4
Oxygen consumption per kg-m at a sub-maximal load

<table>
<thead>
<tr>
<th>Groups</th>
<th>ml O₂/min/kg (x± S.D.)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.20 ± 0.22</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Obese</td>
<td>2.51 ± 0.26</td>
<td>N.S.</td>
</tr>
<tr>
<td>Swimmers</td>
<td>2.18 ± 0.15</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>(ANOVA)</td>
<td>F = 8.077</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td></td>
</tr>
</tbody>
</table>

The mean figures of the oxygen pulse of the three groups are shown in Figure 16, the swimmers obtained the highest value and no significant differences were observed between controls and obese.

Regarding the respiratory quotient no differences were detected among the three groups as with earlier reports (Bray 1977).
Fig. 16 Oxygen pulse in obese, control, and swimmer groups
Table 5
Means and standard deviations of the variations of blood glucose (ΔG) and lactate (ΔL) after a maximal exercise

<table>
<thead>
<tr>
<th></th>
<th>ΔG ± S.D. mmol./l</th>
<th>Groups</th>
<th>ΔL ± S.D. mmol./l</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.79 ± 0.38</td>
<td>N.S.</td>
<td>Control</td>
<td>3.50 ± 1.7</td>
<td>N.S.</td>
</tr>
<tr>
<td>0.71 ± 0.38</td>
<td></td>
<td>Obese</td>
<td>3.73 ± 1.6</td>
<td>p &lt; 0.05</td>
</tr>
<tr>
<td>1.28 ± 0.56</td>
<td></td>
<td>Swimmers</td>
<td>4.66 ± 1.9</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

F = 14.508 ANOVA  
F = 2.372
p < 0.001  
N.S.
Table 5 gives the data of variations of blood glucose and lactate in each group. Although ANOVA yielded significant differences in the ΔG, this was only seen in the swimmers, who exhibited the highest increments (1.28 mmol/l) that was rather similar to the value observed by Koch (1978) in a group of trained boys. With respect to the rise of lactate no differences appeared between obese and control groups, nor between obese and swimmers; however, a slight difference was detected between trained and controls.

Table 6 contains the correlation coefficients and the regression lines between E/P and $PWC_{170}$, absolute and relative values. It is evident that the higher the E/P figures, the lower the functional capacity, as it is reflected with the absolute values and even better with the relative ones of the $PWC_{170}$.

3.3. DISCUSSION

Obese subjects are handicapped when performing a given physical work with respect to lean ones, this fact contributes to their "laziness" and aggravates the well known cycle over-fatness - sedentarism.

The $PWC_{170}$ and $VO_{2max}$ values related to mass units, despite theoretical objections (Bailey et al. 1978), have seemed to prove a good basis of standardization and hence, recommended by IBP investigators (Shephard et al. 1977) in the assessment of aerobic capacity. Based on this assumption we state that the aerobic capacity of the obese boys was significantly lower when compared to the non-obese groups. These results agree with previous findings (Pařízková, Norgan and Ferro-Luzzi 1978, Peña 1981).

Physical fitness is a biological feature dynamically influenced by the combined action of multiple factors—physique, among them—and it is noticeable in Figure 14 that the excess of fat exerts a negative effect upon it, and in fact contri-
Table 6
Regression lines and correlation between E/P index and absolute and relative values of PWC170

(a) E/P Index (x) - PWC170 (y)

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>r</th>
<th>Regression line</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>60</td>
<td>-0.616</td>
<td>y = -126.871x + 305.560</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Trained</td>
<td>20</td>
<td>-0.564</td>
<td>y = -125.434x + 321.363</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Non-trained</td>
<td>20</td>
<td>-0.107</td>
<td>y = -21.695x + 135.696</td>
<td>N.S.</td>
</tr>
<tr>
<td>Obese</td>
<td>20</td>
<td>-0.144</td>
<td>y = 64.668x + 200.934</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

(b) E/P Index (x) - PWC170/BW (y)

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>r</th>
<th>Regression line</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>60</td>
<td>-0.750</td>
<td>y = -3.261x + 7.356</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Trained</td>
<td>20</td>
<td>-0.502</td>
<td>y = -1.369x + 5.141</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Non-trained</td>
<td>20</td>
<td>-0.144</td>
<td>y = -0.485x + 3.230</td>
<td>N.S.</td>
</tr>
<tr>
<td>Obese</td>
<td>20</td>
<td>-0.606</td>
<td>y = -2.185x + 5.360</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

(c) E/P Index (x) - PWC170/LBM (y)

<table>
<thead>
<tr>
<th>Groups</th>
<th>n</th>
<th>r</th>
<th>Regression line</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>60</td>
<td>-0.771</td>
<td>y = -3.125x + 7.804</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Trained</td>
<td>20</td>
<td>-0.498</td>
<td>y = -0.918x + 5.166</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Non-trained</td>
<td>20</td>
<td>-0.197</td>
<td>y = 1.145x + 1.381</td>
<td>N.S.</td>
</tr>
<tr>
<td>Obese</td>
<td>20</td>
<td>-0.666</td>
<td>y = -2.524x + 6.605</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

butes to an elevation of the energy cost of external work. Usually, this energy cost of work is expressed in total values rather than in net ones (Miller 1979); therefore from this viewpoint, work is a more expensive task for the obese than for the lean ones as can be seen in our results where the obese
consumed more oxygen per kg·m of work done (Table 4). This finding, however, does not mean an impairment of the work efficiency since the rate of variation of the steady state \( \dot{V}O_2 \) was the same in the obese as in controls, which is represented by the slopes of the regression lines in Figure 15. Indeed, the cycle ergometer only registers the external work performed and does not consider the work required for moving the pedals. Comparing both lines it is evident that the obese's \( \dot{V}O_2 \) were always higher at each of the work load stages with respect to controls. This could be explained for moving heavier legs, and not to an alteration of the chemical-mechanical coupling mechanism of skeletal muscles which is implied in the term efficiency (Whipp 1975). This interpretation has also been demonstrated in studies carried out in adults by Whipp et al. (1973, 1975), Hansen (1973), and Bray et al. (1977).

The aerobic power of the swimmers was the highest among the three groups, it could be that this superiority was due to the intensive training or the initial selection. It is true that cross-sectional comparisons do not permit us to state that the better performances are due to physical training since the factor of selection is unknown and can play an important role.

The changes in aerobic capacity resulting from habitual physical activity have been widely studied. Kemper et al. (1978) evaluated the effects of two extra lessons of physical education (p.e.) during a whole school year and they did not confirm any improvement in the aerobic power. Mocellin and Wosmund in 1973 reported that in a group of children who ran 1000 meters twice a week for 7 weeks, although an improvement of the running speed was obtained, it was due to a better coordination than to an actual improvement of the aerobic capacity itself. Bar Or and Zwiren (1973), and Hamilton and Andrew (1976) also, did not confirm the effect of p.e. upon improvements in physical fitness, but these studies did not control either the intensity or the duration of exercise. Nevertheless, other studies carried out (Brown et al. 1972,

Furthermore, an inverse situation was reported by Åstrand et al. (1963), who studied thirty of the best Swedish girl swimmers whose average aerobic power was 54 ml/kg min and after they stopped training the $\dot{V}O_{2\max}$ fell to 37 ml/kg min, a figure lower than that for untrained women (Eriksson et al. 1971).

A very interesting follow-up study is being carried out in Canada (Jequier et al. 1977), the Trois-Rivières study (Shephard et al. 1980). In a preliminary report they found significant elevation of the $\dot{V}O_{2\max}$ of those children who took extra exercise programmes with respect to controls. The same improvement was also noted in the PMC/BW and in some skill tests. Other investigations (Burke and Frank 1975, Sidney and Shephard 1978, Andersen et al. 1978, Pollock et al. 1980) revealed that the frequency, duration and intensity of training clearly influenced better $\dot{V}O_{2\max}$ results and induced changes upon body composition (Milesis et al. 1976, Pollock, 1973, Wilmore et al. 1970). In other longitudinal study - Saskatchewan Growth and Development Study - Mirwald (1980) demonstrated "that the growth in $\dot{V}O_{2\max}$ exceeds what one could accept from height and weight percentiles, and suggested that genetic potential and/or level of physical activity could explain these behavior."

As it may be seen, so far it has not been elucidated the particular influence of internal or external factors in the development of aerobic capacity. We agree with Mészáros and Szmodis (1980) suggestion regarding athletes "that their functional superiority could be a consequence of habitual training and not necessarily of a relative better state of structural development."

It is of interest to point out that the $\dot{V}O_{2\max}/kg-m$ of the swimmers was similar to that of the controls (Table 5), in other
words their energy cost of work did not differ; however, their maximum oxygen pulse was more developed, and everybody agrees that this parameter reflects with reliability their better cardio-respiratory adaptation during exercise (Malomsoki 1979, Knipping 1960) enhanced fitness and resistance.

For more than two decades ago it was known that carbohydrates and fats were the main substrate to be utilized in muscular work (Christensen and Hansen 1939), and the interplay between them has been described elsewhere (Astrand 1972, Rosell and Saltin 1973). A major participation of carbohydrates takes place with an increase of the work (Hermansen et al. 1967, Saltin and Hermansen 1967, Saltin and Karlson 1971) and the main source of it is the muscle glycogen. This muscle glycogen could be increased with a high carbohydrate diet and significant improvements in performance obtained (Bergstrom et al. 1967) although according to Karlson and Saltin (1971) this fact has been a little bit exaggerated. Saltin (1978) considered that perhaps the water reserve associated with the glycogen storage in muscle could prevent dehydration and not only a greater glucose reserve from the energetic point of view was the responsible of better performances.

The trained boys achieved significantly the highest increments in blood glucose after maximal exercise, and no differences were obtained between obese and controls. It has been described that the main extramuscular source of carbohydrate is the liver, and during exercise there is a glucose release from the liver derived from glycojenolysis or from gluconeogenesis (Rowell et al. 1965, Hultman 1967, 1978), and this release could be enhanced with physical exercise (Rowell 1971); otherwise, in trained individuals it also has been demonstrated that there is an improvement of the oxidative potential in the muscle and a better utilization of fat (Saltin et al. 1976, Henriksson 1976) which seems to be an explanation of this difference.

When evaluating the ∆L, slight differences were found among the three groups; however, the difference between swim-
mers and obese we presumed was more from the statistical than from the biological point of view. However, the greatest variations in swimmers could be explained, firstly, because the trained boys were able to perform more intense and prolonged work than the non-trained groups, and secondly, because the anaerobic capacity is also influenced by systematic training as has been reported by Matejková et al. (1980). Kindermann et al. (1975) suggested that the anaerobic capacity really becomes apparent in adulthood and is one of the latest physical capacity to be achieved in the growing organism. Unfortunately, we did not measure the maximal anaerobic endurance.

The E/P index represents the quantity of fat related to muscle mass as it was recently reported (Amador et al. 1981a,b) it seems that the higher this relation is the poorer performances could be obtained, mainly in obese and trained subjects. The fact that the most significant correlations were found in the total sample could be due to the broader range of the values involved in the correlation study. The lack of significance in the non-trained group is possibly related to a greater heterogeneity within this group regarding body composition as well as habitual physical activity. Meanwhile, the obese and the swimmers are themselves more homogeneous; the former because of overfatness, the latter due to a common training program.

Since E/P reflects in some way the nutritional status and body composition the relationship found between the index and fitness could be explained considering that physical fitness is a multifactorial biological feature, and we think that the factors non related to E/P influenced the lack of identity in all groups.

Relying upon all the disadvantages of overfatness in physical performance and the tendency to a growing lack of exercise influenced by civilization (Eiben 1977) it is extremely necessary to promote physical activity from early childhood with adequate nutritional habits. These facts are of great importance and could yield a beneficial impact upon human health.
Chapter 4

EFFECTS OF CAFFEINE UPON PHYSICAL FITNESS IN OBESE AND NON-OBSESE BOYS

"He who drinks and has no thirst or eats and has no hunger unlike him whose health is first suffers illness and dies younger"

George Hackett Smith

There is a considerable consumption of methylxanthines - namely caffeine and theophylline - all over the world. These substances are usually found in coffee, tea, chocolate, and many soft drinks.

The possible mechanisms of action, systems involved, and pharmacological effects of caffeine have been described elsewhere (Ritchie 1975). It has been ascribed as an inotropic and chronotropic action on the isolated heart of homothermal animals, presumably connected with its influence on calcium ion exchange (Kukovetz and Pöch 1969). Acts upon the nervous system, although the intrinsic mechanism is not yet confirmed. Rebabian et al. (1972) proposed that since caffeine inhibit phosphodiesterase (the enzyme which inactivates cyclic adenosin monophosphate -3' 5' AMP-) (Butcher and Sutherland 1962) prolongs the presence of 3' 5' AMP in the post-synaptical zone and promotes a longer effect of the activation of the dopaminergic receptors. This fact reduces the threshold of the potential of excitation, thus increasing the neuronal excitability (Waldeck 1973). Other investigators have found increased psychomotor performances and alertness (Lienert and Huber 1966, Fröberg et al. 1969a,b, Selbach 1969, Müller-Limroth 1972) as well as euphoria (Fischbach 1970). In addition, it has been demonstrated that increases the metabolic rate (Strubelt and Sieger 1969, Miller et al. 1974, Acheson 1980) partly due to the increases of the secretion of catecolamines and partly to its calorigenic effects. Bellet et al. (1968, 1969a, 1969b) reported an eleva-
tion of the free fatty acids (FFA) in plasma and in catecholamines excretion following the ingestion of caffeine, interrelating both phenomena, but later was demonstrated that also stimulates lypolysis by itself (Fröberg 1969b, Avogaro 1973). This action has been ascribed as an important mechanism by which physical endurance is improved (Ivy et al. 1978, 1979, Costill et al. 1978), an observation reported in animals (Bedő et al. 1978) and in humans. Since it has been demonstrated that there is a decreased sensitivity to lipolytic stimuli in obese individuals (Opie and Walfish 1963, Gordon 1964, Pinter and Pattel 1969, Gries et al. 1972), including caffeine among them (Acheson et al. 1980), and taking into consideration that in the performance enhancement the lipolytic effect is an important mechanism which takes place (Hickson et al. 1977, Rennie et al. 1976, Costill et al. 1977), it was our purpose to study the effect of this xanthine upon the aerobic capacity of obese children and to compare it with the response obtained in non-obese boys.

4.1. SUBJECTS AND METHODS

Fifteen boys, aged 10.00-14.37 years, were included in this study. None were on any drug therapy. Nine of them were obese --since their body fat percent (%BF) was over 25-- and the other six were non-obese healthy subjects, considered as controls. All of them were subjected to a complete physical examination and to the following measurements:

a) Anthropometric assessment

The instruments and the procedures employed were those previously described in details elsewhere (See Chapter 2, Sample No.1).

The sequence of measurements followed was: Height, Body weight, Triceps skinfold, Biceps skinfold, Subscapular skinfold, Suprailiac skinfold, and Calf skinfold.

The prediction equation developed by Pařízková and Roth (1972) was used for the calculation of the %BF. The BF(kg) was
obtained from the BF and BW; and the LBM(kg) by subtracting BF(kg) from BW.

b) Performance test

Each subject, subsequent to the parents consent, underwent the functional test twice, with two days between them, once with 4 mg/kg of expected BW for the height of Caffeine sodium benzoate per os in 20 ml of tap water, 20 minutes before the performance test, and the other day with 20 ml of water which served as placebo. The sequence of caffeine and placebo studies was randomized. All the recommendations previously described in Chapter 3 were carefully followed.

The IBF methods (Seliger 1970) were followed when determining the performance tests, and consisted of three submaximal work loads (1.0 - 1.5 - 2.0 Watt per kg of BW) lasting each time 6 min, and one of maximum loading, which was started with one-minute load of 2.5 Watt/kg and increased every minute by 15 Watt till the maximal state was reached. The subjects were requested to maintain a constant pedalling rate at approximately 60 rpm. The test was performed on an electrically-braked cycle ergometer (Medicor KE II). Heart rate was recorded by means of chest lead electrocardiogramm (Hellige).

Expired air was collected through a two-way low resistance valve during the last minutes of work until the subject reached the maximal effort by the Douglas method (Weiner and Lourie 1969). The air volume was measured by exhaustion the air from the bags using a dry gasmeter and aliquot samples of expired air were analyzed for oxygen with a RAPOX (Godart-Statham) which was always calibrated prior to each experimental run. The oxygen uptake (VO₂) was determined at the maximal effort (VO₂max) and was recorded in absolute and relative values as described in Chapter 3 (Subjects and Methods).

PWC₁₇₀ was calculated as referred in Chapter 3 and also given absolute and relative values.

c) Statistical analysis

Since all the subjects performed the functional test twice,
once with caffeine and once with water as a placebo, with a random sequence, the differences of the variables studied in each individual were calculated. To test if significant changes occurred in the aerobic capacity due to the ingestion of caffeine, a Student's t test for paired data was performed. In addition, the differences between the obese and the control groups were assessed through a Student's t test for pairwise comparisons.

4.2. RESULTS

Table 7 shows the means and standard deviations of the chronological age, BW, BF(%), and BF(kg) of the obese and controls studied. The obese were of heavier body weight and had greater amounts of fat than the non-obese boys.

<table>
<thead>
<tr>
<th></th>
<th>Obese (n = 9)</th>
<th>Control (n = 6)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>11.567 ± 1.475</td>
<td>11.700 ± 1.400</td>
<td>N.S.</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>64.5 ± 13.3</td>
<td>41.2 ± 4.3</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>30.9 ± 2.3</td>
<td>20.9 ± 3.7</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Body fat (kg)</td>
<td>20.1 ± 5.0</td>
<td>8.7 ± 2.3</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

In Figure 17 are represented the individual changes observed on the PWC<sub>170</sub>—absolute and relative values—due to the ingestion of caffeine with respect to the ingestion of placebo. Only one obese boy was found who reduced his PWC<sub>170</sub> score. As it could be observed the p values obtained through the Student's t test for paired data were all significant. An increase of approximately 13% of the PWC<sub>170</sub> was seen in both groups, after giving caffeine. In Table 8 appear the mean values and standard deviations of PWC<sub>170</sub> in each group. Besides the probability of the variations observed within each group, the p values obtained from the comparisons between obese and controls are shown.
Fig. 17 Changes of PWC$_{170}$ with caffeine (absolute and relative values)
The absolute values did not differ significantly while the relative ones yielded significant different figures.

| Table 6 |
|---------------------|---------------------|-----|
| Absolute and relative values of \(\text{PWC}_{170}\) with caffeine and placebo |
|                      | Obese \((n = 9)\) | Control \((n = 6)\) | \(p^{**}\) |
| \(\text{PWC}_{170}\) |                      |                  |       |
| Caffeine             | 108.7 ± 20.6        | 103.8 ± 12.0     | N.S.  |
| Placebo              | 95.8 ± 17.8         | 91.2 ± 17.1      | N.S.  |
| \(*p < 0.02\)        | \(*p < 0.05\)       |                  |       |
| \(\text{PWC}_{170}/\text{BW}\) |                  |                  |       |
| Caffeine             | 1.73 ± 0.36         | 2.55 ± 0.42      | <0.01 |
| Placebo              | 1.53 ± 0.34         | 2.22 ± 0.44      | <0.01 |
| \(*p < 0.02\)        | \(*p < 0.05\)       |                  |       |
| \(\text{PWC}_{170}/\text{LBM}\) |                  |                  |       |
| Caffeine             | 2.49 ± 0.49         | 3.21 ± 0.41      | <0.02 |
| Placebo              | 2.20 ± 0.47         | 2.81 ± 0.51      | <0.05 |
| \(*p < 0.02\)        | \(*p < 0.05\)       |                  |       |

\(^{*}\)Significance of mean difference between caffeine and placebo — paired data.

\(^{**}\)Significance between obese and controls.

The variations obtained in the \(\dot{\text{V}}\text{O}_{2\text{max}}\) — absolute values and those referred to mass units—of each subject, when caffeine or placebo were given are presented in Figure 18. Only one boy, the same mentioned above, reduced his \(\dot{\text{V}}\text{O}_{2\text{max}}\) when received caffeine, otherwise the two groups showed significant elevations with caffeine. The binary comparisons between groups were highly significant for the relative values, while the absolute was not.
Fig. 18 Changes of $\dot{V}O_2$ max with caffeine (absolute and relative values)
The enhancement obtained in the obese group (11%) was slightly but not significantly higher than that obtained in controls (8%).

4.3. DISCUSSION

It has been demonstrated in the preceding chapter that the oxygen uptake of the obese subjects when performing a submaximal physical task is higher than that of the non-obese. A fact attributable to the extra work load permanently "carried" by the obese due to the greater body weight as fat mass; hence, it is a remarkable handicap when obese children practice sports or play games, in which runs, jumps, or other movements are involved. This relative difficulty may explain why often obese subjects drop out from training programmes and reject in some degree, their participation in physical activities (Peña 1981). However, the absolute values of PWC\textsubscript{170} and \( \dot{V}O_{2\text{max}} \) achieved by the obese were not different from that of the controls (Tables 8 and 9). Certainly, the goal is to get rid of the "extra load" - that is to say extra fat - and probably they will be able to accomplish the "effective" physical work with fair results.

Our results demonstrate that obese and non-obese significantly improved their aerobic capacity when they ingested caffeine prior to the physical performance test (Figures 17 and 18). Moreover, the magnitude of improvement was similar in both groups with the xanthine effect and a lessening of the subjective feeling of tiredness was also seen (Peña et al. 1981).

Acheson et al. in 1980, studied the influence of caffeine on the metabolic rate and substrate utilization in obese and non-obese adults. They concluded that the metabolic rate increased in both groups; however, increases in fat oxidation only occurred in the lean ones. This decreased sensitivity of obese subjects to the lipolytic effect of caffeine was also reported by Daubresse et al. (1973). On the other hand, several observations (Rennie et al. 1976, Hickson et al. 1977) have demonstrated the sparing of muscle glycogen and enhancement in the capacity of endurance when lipolysis is stimulated. Thus,
<table>
<thead>
<tr>
<th></th>
<th>Obese (n = 9)</th>
<th>Controls (n = 6)</th>
<th>p**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VO₂</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>max</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>1958.9 ± 577.4</td>
<td>2148.0 ± 636.2</td>
<td>N.S.</td>
</tr>
<tr>
<td>Placebo</td>
<td>1754.1 ± 530.3</td>
<td>1975.3 ± 577.2</td>
<td>N.S.</td>
</tr>
<tr>
<td>*p &lt; 0.01</td>
<td></td>
<td>*p &lt; 0.02</td>
<td></td>
</tr>
<tr>
<td><strong>VO₂</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>max/BW</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>30.57 ± 6.39</td>
<td>52.05 ± 13.81</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Placebo</td>
<td>27.40 ± 6.22</td>
<td>47.98 ± 13.19</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>*p &lt; 0.01</td>
<td></td>
<td>*p &lt; 0.01</td>
<td></td>
</tr>
<tr>
<td><strong>VO₂</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>max/LBM</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td>44.10 ± 8.34</td>
<td>65.91 ± 17.53</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Placebo</td>
<td>39.47 ± 7.95</td>
<td>60.65 ± 16.48</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>*p &lt; 0.01</td>
<td></td>
<td>*p &lt; 0.01</td>
<td></td>
</tr>
</tbody>
</table>

*Significance of mean differences between caffeine and placebo (paired data).
**Significance between obese and controls.

the elevation of FFA, as an extra source of substrate for the working muscles have been considered as an important mechanism to explain these findings. Ivy et al. (1978, 1979), and Costill et al. (1978) confirmed these observations but using caffeine, in non-obese individuals; however, as far as we are aware no studies have been carried out to assess the influence of caffeine upon the aerobic capacity of obese subjects. After the intake of caffeine the aerobic oxidation improved on the basis of lactic acid metabolism in obese patients according to Barta et al. (1982). In a recent paper Wilcox (1981) reported
in rats greater fat loss and weight reduction when caffeine was given before the training sessions.

Several questions arise: Is the lipolytic action of caffeine manifested when caffeine is associated to physical exercise? Does caffeine act through other mechanism upon fitness - e.g. increasing neuronal excitability through a reduction of threshold for excitation (Waldeck 1973) or something else? Or is its influence related to its euphoriant effect (Fischbach 1970)? In fact, we did not measure either the rate of lypoysis, or neuronal excitability; therefore, no definite conclusion regarding the intrinsic mechanisms involved, could be reached. Nonetheless, better performances were seen and this fact could be a sort of aid at the beginning of the training programmes for those grossly obese patients -otherwise healthy- who are extremely handicapped when performing physical exercise. But it should be underlined that the motivation of the patient is of prime importance and only if this measure fails the administration of caffeine should be considered.

Several authors (Miller et al. 1974, Acheson et al. 1980) have suggested the use of caffeine as a supplementary measure in slimming regimes considering its effect as a thermogenic agent. Our opinion is that it is better to establish dietary limitations and to promote physical activities because these aspects are more physiological and could be subjected to voluntary restriction by means of behavioural regulations.
Chapter 5

VARIATIONS OF BODY COMPOSITION AND PHYSICAL FITNESS
WITH DIFFERENT TREATMENTS

"Man ist, was er ist."
J. W. von Goethe

Regulation of body mass and body composition is dependent on energy intake, energy expenditure, and on the behaviour of many regulating mechanisms. The last factors are numerous, complex, and still not well understood (Fox 1974, Johnson 1979). Indeed, the first two factors can be controlled and their combination seems to be the most physiological way to reduce fat (Parizková 1977).

Hippocrates taught that "diseases which arise from repletion are cured by depletion." The oldest and most widely used approach in treating obesity deals with dietary restriction. We shall try to summarize and briefly describe several diets that have been used:

- **Total fasting and semistarvation diets**: These diets induce great weight loss, namely at the beginning of the treatment, and this weight reduction results from the breakdown of lean rather than adipose tissues (Forbes 1970, Huncie and Hilditch 1974); on the other hand, a lack of carbohydrate ingestion promotes substantial water and mineral excretion (Bloom and Mitchell 1960, Drenick et al. 1969). Hence, the results are not so "successful", since obesity means excessive accumulation of fat and treatment aims to reduce the amount of fat and the least reduction of lean body mass as possible. Moreover, these diets are absolutely disapproved in children and adolescents since the events of growth and development could be seriously impaired and severe nutritional deficiencies could arise. Among other deleterious effects reported we shall cite:
functional impairment of glomerular filtration and hepatic function (Rozental et al. 1968, Drenick et al. 1970, Edgren and Wester 1971), hyperbilirubinemia (Barret 1971), disturbance of acid base equilibrium (Drenick 1975), increased uric acid excretion (Drenick 1965), induced neutropenia (Drenick and Alvarez 1971), impairment of some endocrine function (Schachner et al. 1968, Portnay et al. 1974), and also the risk of sudden death have been described (Norbury 1964, Spencer 1968, Garnett et al. 1969).

- **Protein-sparing diets:** These diets were in vogue two decades ago. Calloway and Spector in 1954 stated that subjects with a negative energy balance were also in negative nitrogen balance. Later, when the protein intake was elevated many authors observed a better nitrogen balance (Apfelbaum et al. 1970, Genuth et al. 1974, Baird et al. 1974). With the advent of parenteral nutrition, positive nitrogen balance was seen in spite of low caloric intake (Jeejeebhoy 1976). Flatt and Blackburn (1974) and Jourdan et al. (1974) suggested the biochemical basis for these diets in obesity, and Garrow (1978) made an extensive review of them. Bistrian et al. (1976) also recommended these diets for obese diabetic inpatients, mainly in those diabetics with some endogenous insulin reserve. Although an actual positive nitrogen balance could take place in children, growth impairment is not avoided.

- "**Low-carbohydrate**" ketogenic diets: These groups of diets -with two common aspects: a low carbohydrate content and "ad libitum" consumption of fats and proteins,- appeared in the 19th century and several decades ago arraised up again (Lyon and Dunlop 1932, Pennington 1953a, 1953b, Taller 1961). In 1972, Atkins wrote a "best-seller" with sensationalism and commercial purpose, describing the "miraculous" effect of the diet, which was strongly criticized by the Council of Foods and Nutrition (1973).

The question of varying extents of weight reduction on these diets has been the subject of great controversy (Kekwick and Pawan 1956, Kinsell et al. 1964). Significant greater weight reductions have been reported (Rabast et al.-1977,
Kasper et al. 1973, Peña et al. 1979a) but this could be due to the greater water depletion secondary to the decrease of the glycogen pool. On the other hand, the potentiality to develop a hyperlipemia due to the unlimited intake of saturated fats, and cholesterol-rich foods, as well as to the nutritional imbalance that could be produced have been pointed out.

- Conventional reducing diets: These diets are designed to provide enough protein, minerals, and vitamin to meet lean tissue growth requirements, and to reduce the intake of foodstuffs with a high energy density. This system is relatively safe, but the results have been quite disheartening since many patients drop out and feel disappointed (Waxler and Leef 1969, Miller and Parsonage 1975). That is why it is of primary importance to act upon the feeding behaviour of the obese subject and to promote positive changes of their attitude (Brownell and Stunkard 1978).

- Fiber diets: Recently, fiber has been considered as a nutrient of importance in its own right (Cummings 1978) and the role it plays in nutrition and health has been stressed (Trowell 1972a, 1972b, 1973, Spiller and Amen 1977). Many diseases and symptoms have been related to some extent to the poor fiber consumption such as constipation (Burkitt 1979), diverticulosis (Burkitt 1975b), ischaemic heart disease (Trowell 1972a, 1973), diabetes mellitus (Cleave 1969, Trowell 1975), large bowel cancer (Burkitt 1971, Crosby 1978), obesity (Van Itallie 1978), among them; however, other reports doubt these findings (Kelsay 1978).

Among the multiple etiological factors of obesity, the underconsumption of fiber and overconsumption of sugar and fats have been proposed (Beyer and Flynn 1978). Several studies have shown a progressive and significant decrease in the consumption of fiber and physical activity since the 19th century (Antar et al. 1964, Cummings 1973, Robertson 1972), while the prevalence of obesity has increased sharply in developed countries during this century on the basis of epidemiological observations (Van Itallie 1978).
The term "fiber" has not yet been well clarified. One of the oldest methods, which is the currently approved by the Association of Official Analytical Chemists, consists in the sequential extraction with hot dilute acid followed by diluted alkali, but by this method sensible losses of different fibers occurred (Tyler 1975). As mentioned by Van Soest (1978), the methodology itself must be directed toward two separate goals: either for research purposes, where structural analysis is required; or for surveys or quality control work that the methods must be rapid and convenient although some details may be sacrificed. Besides this "structural" definition, dietary fiber has also been defined as the residue of plant cells resistant to digestion by the alimentary enzymes (Trowell 1973). The main components are cellulose, hemicellulose, pectins, and lignins present in the plant cell walls. To these it must be added the interior undigested polysaccharides such as guar gums, and other leguminous galactomannans (Trowell et al. 1976).

According to its component in monosaccharides we could summarize as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Monosaccharides component</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose</td>
<td>1-4 D Glucose</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>Hexose, Pentose, Urionic acids</td>
</tr>
<tr>
<td>Pectins</td>
<td>Pentose</td>
</tr>
<tr>
<td>Lignin</td>
<td>Phenylpropane polymer</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Mannose, Galactose</td>
</tr>
<tr>
<td>Other leguminous galactomannans</td>
<td>Glactose</td>
</tr>
</tbody>
</table>

Cellulose is not digested by the human small intestine, although 15 percent approximately is degraded by intestinal flora, while hemicellulose may be degraded up to 85% in the large intestine (Southgate 1973).

The different components of dietary fibers may have different effects. For example, cellulose and hemicellulose are able to absorb water and can thus act as bulking agents; on the other hand lignin absorbs organic materials, while the galactomannans modify the viscosity of the intestinal content (Goulder 1980).
Based on some of its physico-chemical properties, dietary fiber could contribute to the prevention of obesity as it has been recently discussed by Heaton (1973), Trowell (1975), and Van Itallie (1978). The possible mechanisms considered are: (1) reduces the energy density of the diet, (2) promotes chewing, therefore the rate of ingestion is reduced and the increased secretion of saliva and gastric juice contribute to gastric distension and satiety, (3) leaves a larger residue of undigested material in the intestine and due to its bulking effects promotes abdominal distension and (4) reduces slightly the absorption efficiency of the intestine. As it could be appreciated these properties could be useful in the dietary approach of obese individuals; however, quantitative and qualitative aspects of the dietary fiber should be carefully assessed since impairments in the mineral and fat absorption could take place (Cummings 1978).

- Physical exercise: Bruch in 1940, and later many other authors (Bloom and Eidex 1967a, 1967b, Harper 1969) found that many obese individuals ate less than non-obese ones and they ascribed their overfatness to a reduced physical activity. Bullen et al. (1964) and Mayer (1968) using cinematographic recordings reported that obese children were less active than lean ones; nonetheless, other reports do not agree with those findings (Stefanik et al. 1959, McCarthy 1966, Wilkinson 1977).

To demonstrate that inactivity is a major factor in the etiology of obesity is a very complex and difficult task. The methodologies available are not accurate enough to measure with reliability the energy intake and energy expenditure for detecting the imbalance required to produce obesity (Garrow 1978). In spite of these difficulties, it seems that an exercise programme is an important part of the management of the obese patient (Allen and Quigley 1977, Pařízková 1977).

We have already commented in Chapter 3 some morphofunctional changes promoted by physical training. Moreover, authoritative works proved the positive effect of exercise upon lipid metabolism in experimental animals (Pařízková 1964, Pařízková and Poledne 1974, Pitts and Bull 1977) as well as in humans.

On the other hand, several investigators (Miller 1978, 1979, Garrow 1978) considered that the effect of exercise in the treatment of obesity has been overlooked. Indeed, Girandola (1976) reported weight gain in obese women treated with exercise and Björntorp et al. (1970, 1977) showed increase in body fat. It has appeared frequently in the literature that exercise alone did not produce significant weight reductions (Gwinup 1975, Sullivan 1976, Zuti and Golding 1976). We have tested two different therapeutic regimes for a two week period, with the same energy intake and only differed in an exercise programme, differences in body weight were not found; however, a greater significant reduction of body fat was obtained in those children who exercised (Peña et al. 1980a).

Considering all these aspects, the aims of our study were:

- To study the variations of body composition and physical fitness of obese children following a physical training programme.

- To study the influence of a relatively high fiber content in the diet upon body composition and physical fitness.

- To point out the importance of the assessment of body composition during the treatment of obesity.

- To determine if the diet with 15 g of crude fiber produces impairment of lipid absorption and/or in the serum concentration of several minerals.

5.1. SUBJECTS AND METHODS

Eighty obese children (40 girls and 40 boys), otherwise healthy, ranging from 10.00 to 14.99 years of age were studied under ward conditions during four weeks. Obesity was considered when the percent of body fat (\(BF\)) was above 30 and 25 for girls and boys, respectively. At the time of admission each of them was subjected to a complete physical examination, and to the following measurements:
a) **Anthropometric assessment**

The measurements were taken with the same instruments and following the same procedures described in detail for Sample No.1 in Chapter 2.

The sequence of measurements was: Height, Body weight, Triceps skinfold, Biceps skinfold, Subscapular skinfold, Suprailiac skinfold, and Calf skinfold.

The 1W/AH was estimated using as standards the data of the Budapest Growth and Development Study (Eiben et al. 1971). The %BF was calculated as explained before using Pařízková and Roth's (1972) prediction equations. The body fat mass in kilograms (BF/kg) was obtained from the %BF and the BW, and the lean body mass (LBM/kg) by subtracting the BF from the BW.

b) **Performance test**

Prior to testing, the same recommendations that appear in Chapter 3 were carefully followed. The exercise protocol employed was also the same described previously, belonging to the IBP (Seliger 1970) and consisted of three submaximal work loads, and after a pause of two minutes started the loadings until the maximum effort was reached.

The test was performed on an electrically braked cycle ergometer (Medicor KE-11), and the pedalling frequency was set at 50 rpm. The heart rate was monitored every minute by means of chest lead electrocardiogram (Hellige).

The oxygen uptake (VO₂) was determined every minute during the last minutes until the subject achieved the maximal effort (VO₂max) by the Douglas bag method (Weiner and Lourie 1969). The child breathed through a low resistance valve, the air volume was measured by a dry gasmeter and aliquot samples of expired air were analyzed for oxygen and carbon dioxide with a Rapox (Godart-Statham) and a Capnograph, respectively. The gas analyzers were calibrated prior to each experimental run.

PWC<sub>170</sub> was calculated as referred in Chapter 3. VO₂max and PWC<sub>170</sub> have been recorded in their absolute values and related to the BW and LBM.
c) Bone age and pubertal ratings

For each subject an X-Ray of the left hand and wrist was performed for determining bone age, according to Schmid and Moll's atlas (1960) and the pubertal status following Tanner's criteria (1962).

d) Treatments

Each sex was distributed according to their chronological age, bone age, and pubertal status into four homogeneous groups. All the groups received the same energetic intake, and also the same proportion of protein, fat, and carbohydrate; but differed only in the fiber content of the diet or in a physical training programme. The quantity of food ingested was carefully watched, followed, and recorded.

GROUP I: They were given a diet of 4.18 MJ per day with a protein:fat:carbohydrate ratio of 2:3:5, respectively. The crude fiber content of the diet was approximately 15 g per day and this increment was obtained from natural foodstuff sources, using a Hungarian composition table (Tarján and Lindner 1978). Besides, they joined to a training programme consisting of two sessions per day, 5 times a week, following a fixed schedule. Each session lasted 20 minutes and started with an initial warming up by jogging. Thereafter followed a work load on a cycle ergometer with an intensity of 70% of the maximal oxygen uptake recorded at admission during 15 minutes. The exercise was finished with jogging and gradually decreased up to relaxation.

GROUP II: They also received a diet of 4.18 MJ, but with a fiber content of an "average diet" considered of about 5-6 g per day. They also trained with the same programme as GROUP I.

GROUP III: They fed on with the same diet as GROUP I but with no training programme.

GROUP IV: They received the same diet as GROUP II and did not join the training programme.

At the end of the four week period, all the variables mentioned above were assessed again.
We also determined the plasma concentration of iron, calcium, zinc, and copper with a Perkin Elmer atomic absorption spectrophotometer (PE-403) in fifteen children, selected randomly among those who received fiber diet. To each of them a Van de Kamer test was performed before and after the fiber diet.

e) **Statistical analysis**

The means and standard deviations of all the parameters studied and of their difference—before and after treatment—were calculated independently for girls and for boys in each group. To assess the variation of each variable within groups a paired Student's t test was carried out.

A one-way ANOVA was performed to test the mean differences of the variation of every parameter among the 4 groups, considering sex separately, afterward if F ratio was found to be significant, binary comparisons between groups through a Student's t test were done.

5.2. RESULTS

a) **Anthropometric variables**

The means and standard deviations of BW, %BF, BF(kg), LBM(kg), and IW/AH before and after the 4 week period of different treatments appear in Tables 10 and 11 for the girls and boys, respectively. The t tests for paired series with respect to the mean differences within each group were highly significant (p < 0.001), showing reductions in all the anthropometric parameters studied.

To determine whether differences exist in the decrements of BW (dBW) and body fat percent (d%BF) among the 4 groups, one-way ANOVA tests were done. These decrements and the F ratios calculated for dBW and d%BF are presented in Figure 19. Although F figures were significant for dBW, the pairwise comparisons only yielded significant differences between groups I and IV (p < 0.01) and between group II and IV (p < 0.02) in the females, and between groups I and IV (p < 0.05) in the males, as it is represented in Table 12. Regarding d%BF in both sexes, highly
### Table 10

Body weight, body composition, and IW/AH in obese girls before and after different treatments

<table>
<thead>
<tr>
<th></th>
<th>Group I N = 10</th>
<th>Group II N = 10</th>
<th>Group III N = 10</th>
<th>Group IV n = 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body weight (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>71.0±15.3</td>
<td>67.3±9.2</td>
<td>64.2±10.9</td>
<td>65.9±15.2</td>
</tr>
<tr>
<td>after</td>
<td>66.2±14.4</td>
<td>63.1±8.8</td>
<td>60.8±10.4</td>
<td>63.3±14.9</td>
</tr>
<tr>
<td>p&lt;0.001 - S</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>Body fat (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>34.8±4.2</td>
<td>35.9±2.6</td>
<td>33.8±2.9</td>
<td>36.4±2.2</td>
</tr>
<tr>
<td>after</td>
<td>30.8±3.2</td>
<td>32.6±2.8</td>
<td>32.0±3.2</td>
<td>35.3±2.3</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>Body fat (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>25.2±7.4</td>
<td>24.3±4.4</td>
<td>21.9±5.3</td>
<td>24.2±6.5</td>
</tr>
<tr>
<td>after</td>
<td>20.9±6.5</td>
<td>20.7±4.0</td>
<td>19.7±5.2</td>
<td>22.5±6.3</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>L.B.M. (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>46.1±8.3</td>
<td>43.0±5.0</td>
<td>42.2±5.7</td>
<td>41.8±8.9</td>
</tr>
<tr>
<td>after</td>
<td>45.6±8.2</td>
<td>42.4±5.1</td>
<td>41.0±5.3</td>
<td>40.9±8.3</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>IW/AH (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>144.3±13.0</td>
<td>145.4±17.6</td>
<td>137.6±77.4</td>
<td>138.2±18.8</td>
</tr>
<tr>
<td>after</td>
<td>134.2±12.5</td>
<td>136.3±15.9</td>
<td>130.4±26.1</td>
<td>133.0±18.8</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

*S. Significance of mean differences before and after treatment.

Significant F values were obtained (p < 0.001), and the mean reductions of %BF in those groups in which exercise was involved were clearly greater than those without it, a result that was confirmed through the pairwise comparisons, as it is shown in Table 13. When the groups were matched to evaluate the effect of the fiber content of the diet, although slightly higher re-
Fig. 19 Decrement of body weight (dBW) and body fat percent (d%BF) in obese children with different treatments

Fig. 20 Decrement of lean body mass (dLBM) and of body fat (dFB) in obese children with different treatments
Table II

Body weight, body composition, and IW/AB in obese boys before and after different treatments

<table>
<thead>
<tr>
<th></th>
<th>Group I N = 10</th>
<th>Group II N = 10</th>
<th>Group III N = 10</th>
<th>Group IV N = 10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body weight (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>73.2±13.0</td>
<td>71.2±22.9</td>
<td>64.7±11.2</td>
<td>70.2±16.3</td>
</tr>
<tr>
<td>after</td>
<td>68.3±12.7</td>
<td>67.0±22.0</td>
<td>60.6±11.3</td>
<td>66.7±15.6</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>Body fat (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>32.8±2.4</td>
<td>32.5±2.4</td>
<td>30.5±2.4</td>
<td>32.0±2.5</td>
</tr>
<tr>
<td>after</td>
<td>28.9±3.0</td>
<td>29.2±4.5</td>
<td>28.8±2.7</td>
<td>30.4±2.5</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>Body fat (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>24.2±5.3</td>
<td>23.9±10.5</td>
<td>19.9±4.7</td>
<td>22.6±6.0</td>
</tr>
<tr>
<td>after</td>
<td>20.0±5.1</td>
<td>20.4±9.7</td>
<td>17.7±4.7</td>
<td>20.5±5.7</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>L.B.M. (kg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>49.0±8.0</td>
<td>47.3±12.6</td>
<td>44.8±6.9</td>
<td>47.6±10.6</td>
</tr>
<tr>
<td>after</td>
<td>48.3±8.0</td>
<td>46.6±12.4</td>
<td>42.9±7.1</td>
<td>46.2±10.3</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td><strong>IW/AB (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>before</td>
<td>149.5±18.0</td>
<td>145.7±19.8</td>
<td>144.9±12.9</td>
<td>163.6±28.8</td>
</tr>
<tr>
<td>after</td>
<td>139.0±18.2</td>
<td>137.4±19.3</td>
<td>134.5±13.8</td>
<td>153.5±27.3</td>
</tr>
<tr>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

*S*: Significance of mean differences before and after treatment.


ductions were seen, they were not statistically significant, neither in boys nor in girls.

In Figure 20 are represented the decrements of the BF(kg) (dBPFkg) and of the LBM(kg) (dLBMkg). ANOVA yielded, in both sexes, significant differences for both variables (p<0.001). Moreover, the greatest body fat losses were achieved in group I.
Table 12
Binary comparisons for the decrement of body weight in four groups of obese children with different treatments

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(3.920)</td>
<td>(2.071)</td>
<td>(1.154)</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.01</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(2.767)</td>
<td>(0.917)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.02</td>
<td>N.S.</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(1.851)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Boys:

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(2.957)</td>
<td>(1.376)</td>
<td>(1.581)</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.05</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(1.376)</td>
<td>(0.205)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(1.581)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 13
Binary comparisons for the decrement of body fat percent in four groups of obese children with different treatments

Girls:

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(7.204)</td>
<td>(5.466)</td>
<td>(1.814)</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(5.393)</td>
<td>(3.652)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.01</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(1.738)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Boys:

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(4.310)</td>
<td>(5.191)</td>
<td>(1.364)</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p &lt; 0.001</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(4.067)</td>
<td>(3.830)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.01</td>
<td>p &lt; 0.01</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(0.239)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ) in brackets: Student's t value
followed by group II; and the smallest reduction was obtained by group IV. The binary comparisons (Table 14) revealed differences between the training groups (e.g. I and II) with respect to the others \( (p < 0.001) \). Again, when comparing those groups with a fiber diet, though they lost more body fat than the other ones these magnitudes were not significant. On the other hand, groups I and II decreased their LBM in a small quantity (less than 15% of the total mass losses), while groups III and IV exhibited greater decrements of LBM, namely group III; and even more marked in boys than in girls. In Table 15 appear the t values and its significance.

**Table 14**

Binary comparisons for the decrement of body fat (kg) in four groups of obese children with different treatments

**Girls:**

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(4.681)</td>
<td>(3.617)</td>
<td>(0.904)</td>
</tr>
<tr>
<td></td>
<td>( p &lt; 0.001 )</td>
<td>( p &lt; 0.001 )</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(3.777)</td>
<td>(2.712)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( p &lt; 0.01 )</td>
<td>( P &lt; 0.02 )</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(1.064)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Boys:**

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>(5.071)</td>
<td>(4.787)</td>
<td>(1.588)</td>
</tr>
<tr>
<td></td>
<td>( p &lt; 0.001 )</td>
<td>( p &lt; 0.001 )</td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>(3.483)</td>
<td>(3.199)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( p &lt; 0.01 )</td>
<td>( p &lt; 0.01 )</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>(0.284)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N.S.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

( ) in brackets: Student's t value
Table 15

Binary comparisons for the decrement of lean body mass (kg) in four groups of obese children with different treatments

**Girls:**

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.276</td>
<td>4.345</td>
<td>0.207</td>
</tr>
<tr>
<td></td>
<td><em>p &lt; 0.05</em></td>
<td><em>p &lt; 0.001</em></td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>4.138</td>
<td>2.069</td>
<td>N.S.</td>
</tr>
<tr>
<td></td>
<td><em>p &lt; 0.001</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>2.069</td>
<td>N.S.</td>
<td></td>
</tr>
</tbody>
</table>

**Boys:**

<table>
<thead>
<tr>
<th>Groups</th>
<th>IV</th>
<th>III</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>2.936</td>
<td>5.028</td>
<td>0.128</td>
</tr>
<tr>
<td></td>
<td><em>p &lt; 0.001</em></td>
<td><em>p &lt; 0.001</em></td>
<td>N.S.</td>
</tr>
<tr>
<td>II</td>
<td>4.894</td>
<td>2.809</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>p &lt; 0.001</em></td>
<td><em>p &lt; 0.02</em></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>2.085</td>
<td>N.S.</td>
<td></td>
</tr>
</tbody>
</table>

( ) in brackets: Student's t value

The variations of the so-called IB/AB in all the groups are shown in Figure 21, where it is appreciable that the groups of boys do not differ among them, but in girls significant variations among the groups were obtained, and the binary tests revealed differences between group I and the non-exercising groups (III and IV), as well as group II which differs from group IV.

**b) Physical fitness**

The absolute and relative values of the PWC<sub>170</sub> of the obese girls before and after treatment are shown in Table 16. The tests for paired data revealed significant improvements for the PWC<sub>170</sub>, a result that was much more remarkable in those who
Fig. 21 Decrements of IW/AH (dIW/AH) in obese children with different treatments
Table 16

PWC<sub>170</sub> - absolute and relative values - of obese girls before and after different treatments

<table>
<thead>
<tr>
<th>Groups</th>
<th>PWC&lt;sub&gt;170&lt;/sub&gt;</th>
<th>PWC&lt;sub&gt;170&lt;/sub&gt; / BW</th>
<th>PWC&lt;sub&gt;170&lt;/sub&gt; / LBM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Dif.</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>90.8</td>
<td>103.8</td>
<td>13</td>
</tr>
<tr>
<td>S.D.</td>
<td>22.69</td>
<td>25.62</td>
<td>5.98</td>
</tr>
<tr>
<td>II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>73.6</td>
<td>87.0</td>
<td>13.4</td>
</tr>
<tr>
<td>S.D.</td>
<td>14.42</td>
<td>15.45</td>
<td>4.45</td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>87.8</td>
<td>92.0</td>
<td>4.2</td>
</tr>
<tr>
<td>S.D.</td>
<td>17.8</td>
<td>17.2</td>
<td>5.63</td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \bar{x} )</td>
<td>87.8</td>
<td>91.2</td>
<td>3.4</td>
</tr>
<tr>
<td>S.D.</td>
<td>20.53</td>
<td>20.47</td>
<td>3.13</td>
</tr>
</tbody>
</table>

ANOVA

\[ F = 11.962 \text{ ****} \]

\[ F = 7.308 \text{ ****} \]

\[ F = 6.941 \text{ ****} \]

**BINARY**

<table>
<thead>
<tr>
<th>t</th>
<th>I-II</th>
<th>I-III</th>
<th>I-IV</th>
<th>II-III</th>
<th>II-IV</th>
<th>III-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>0.180</td>
<td>3.964</td>
<td>4.317</td>
<td>4.137</td>
<td>4.496</td>
<td>0.360</td>
</tr>
<tr>
<td>t</td>
<td>0.020</td>
<td>2.893</td>
<td>3.706</td>
<td>2.824</td>
<td>3.686</td>
<td>0.863</td>
</tr>
<tr>
<td>t</td>
<td>N.S.</td>
<td>N.S.</td>
<td>***</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

**PROBABILITY:**

* < 0.05
** < 0.02
*** < 0.01
**** < 0.001

S - Significance of mean differences before and after treatment (paired series)
### Table 17

<table>
<thead>
<tr>
<th>Groups</th>
<th>PWC_{170}</th>
<th>PWC_{170}/BW</th>
<th>PWC_{170}/LBM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Dif.</td>
</tr>
<tr>
<td>I</td>
<td>X</td>
<td>99.2</td>
<td>110.1</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>26.54</td>
<td>29.72</td>
</tr>
<tr>
<td>II</td>
<td>X</td>
<td>94.8</td>
<td>106.0</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>18.33</td>
<td>21.09</td>
</tr>
<tr>
<td>III</td>
<td>X</td>
<td>96.3</td>
<td>100.4</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>29.3</td>
<td>31.6</td>
</tr>
<tr>
<td>IV</td>
<td>X</td>
<td>96.9</td>
<td>99.2</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>30.88</td>
<td>31.5</td>
</tr>
</tbody>
</table>

**ANOVA**

- F = 6.147 ***
- F = 5.633 ***
- F = 2.455 N.S.

<table>
<thead>
<tr>
<th>BC</th>
<th>I-II</th>
<th>I-III</th>
<th>I-IV</th>
<th>II-III</th>
<th>II-IV</th>
<th>III-IV</th>
<th>N.S.</th>
<th>N.S.</th>
<th>N.S.</th>
<th>N.S.</th>
<th>N.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.120</td>
<td>2.762</td>
<td>3.042</td>
<td>2.882</td>
<td>3.082</td>
<td>0.280</td>
<td>N.S.</td>
<td>0.371</td>
<td>1.169</td>
<td>2.041</td>
<td>1.566</td>
</tr>
<tr>
<td>II</td>
<td>0.252</td>
<td>2.015</td>
<td>3.275</td>
<td>1.763</td>
<td>3.275</td>
<td>1.511</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
<tr>
<td>III</td>
<td>0.371</td>
<td>1.169</td>
<td>2.041</td>
<td>1.566</td>
<td>2.412</td>
<td>0.872</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
<td>N.S.</td>
</tr>
</tbody>
</table>

**PROBABILITY:**

- * < 0.05
- ** < 0.02
- *** < 0.01
- **** < 0.001

S - Significance of mean difference before and after treatment (paired series)
attached to the exercise programme as part of the treatment. The ANOVA yielded differences among the groups (F = 11.962; p < 0.001), and the t test for binary comparisons were significant between exercising groups with respect to non-exercising ones. Differences, otherwise, were not seen either between groups I and II, or between III and IV. Something similar was obtained when the relative values of PWC were analyzed, as it is appreciable in Table 16.

Table 17 presents the data obtained in boys. Improvements were observed in all the groups after treatment, excepting for group III respecting PWC\textsubscript{170}, although the relative values varied significantly. Differences among groups were seen in PWC\textsubscript{170} and PWC/BW, but not the PWC\textsubscript{170}/LBM variations. The binary comparisons of PWC\textsubscript{170} indicate that those groups in which exercise was included (I and II) differed from the others (III and IV), though the fitness enhancement was not in the same magnitude as obtained in girls. Otherwise, a significant response became apparent only between group I and IV, and between II and IV for the PWC\textsubscript{170}/BW; and for PWC\textsubscript{170}/LBM a very small difference was seen between II and IV (p < 0.05) that is more significant from the statistical than from the biological point of view.

The maximal oxygen uptake figures increased slightly with the different treatments. In group III of males, however, no statistical differences were detected, but in that group a great variance is noticeable, indeed the $\dot{V}O_{2\max}$ measurements variability is rather high. When the values were referred to mass units (BW and LBM) the mean differences appeared significant for all groups.

Among groups, no differences were obtained either in girls or in boys, as it can be seen in Table 18 and 19, respectively.

c) Fat absorption and mineral concentrations in serum

Table 20 shows that the fat absorption, tested through a Van de Kamer test, remained unaltered with the 15 g fiber diet given during the period of 4 weeks.
### Table 18
Maximal oxygen consumption - absolute and relative values - of obese girls before and after different treatments

<table>
<thead>
<tr>
<th>Groups</th>
<th>( \dot{V}O_{2\max} )</th>
<th>( \dot{V}O_{2\max}/BW )</th>
<th>( \dot{V}O_{2\max}/LBM )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Dif.</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>1775.0</td>
<td>1795.4</td>
<td>20.4</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>1818.5</td>
<td>1837.1</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>1721.8</td>
<td>1739.1</td>
<td>17.3</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>1744.6</td>
<td>1756.8</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ANOVA

- B C t: I-II: 0.21 N.S.
- I O t: I-III: 0.38 N.S.
- N M t: I-IV: 0.94 N.S.
- A P t: II-III: 0.14 N.S.
- M A t: II-IV: 0.73 N.S.
- Y R t: III-IV: 0.58 N.S.

F = 0.326 N.S.  F = 2.470 N.S.  F = 1.681 N.S.

### Comparison

- PROBABILITY: * < 0.05  ** < 0.02  *** < 0.01  **** < 0.001

'S': Significance of mean differences before and after treatment (paired series)
### Table 19
Maximal oxygen consumption – absolute and relative values – of obese boys before and after treatment and its variations with different treatments

<table>
<thead>
<tr>
<th>Groups</th>
<th>( \dot{VO}_{2\text{max}} )</th>
<th>( \dot{VO}_{2\text{max}}/\text{BW} )</th>
<th>( \dot{VO}_{2\text{max}}/\text{LBM} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Dif.</td>
</tr>
<tr>
<td>X</td>
<td>2045.2</td>
<td>2082.0</td>
<td>36.8</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>277.65</td>
<td>299.64</td>
</tr>
<tr>
<td>I</td>
<td>1864.3</td>
<td>1893.3</td>
<td>29.30</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>364.00</td>
<td>368.00</td>
</tr>
<tr>
<td>II</td>
<td>1907.1</td>
<td>1930.4</td>
<td>23.30</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td>266.00</td>
<td>260.3</td>
</tr>
<tr>
<td>III</td>
<td>1900.5</td>
<td>1911.8</td>
<td>11.30</td>
</tr>
<tr>
<td>IV</td>
<td>S.D.</td>
<td>233.0</td>
<td>236.6</td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th></th>
<th>F = 0.357 N.S.</th>
<th>F = 1.4953 N.S.</th>
<th>F = 1.6810 N.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B C t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I O t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N M t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A P t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R A t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y R t</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I S S</td>
<td>PROBABILITY: * &lt;0.05 ** &lt;0.02 *** &lt;0.01 **** &lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S - Significance of mean differences before and after treatment (paired series)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 20
Fecal fat excretion before and after a fiber diet

<table>
<thead>
<tr>
<th>Before (g/day)</th>
<th>After (g/day)</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.9</td>
<td>5.0</td>
<td>0.1</td>
</tr>
<tr>
<td>3.6</td>
<td>3.7</td>
<td>0.1</td>
</tr>
<tr>
<td>3.2</td>
<td>3.2</td>
<td>0</td>
</tr>
<tr>
<td>1.6</td>
<td>1.4</td>
<td>-0.2</td>
</tr>
<tr>
<td>2.6</td>
<td>2.4</td>
<td>-0.2</td>
</tr>
<tr>
<td>3.3</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>4.8</td>
<td>4.8</td>
<td>0</td>
</tr>
<tr>
<td>4.8</td>
<td>4.8</td>
<td>0</td>
</tr>
<tr>
<td>3.6</td>
<td>3.7</td>
<td>0.1</td>
</tr>
<tr>
<td>4.2</td>
<td>4.3</td>
<td>0.1</td>
</tr>
<tr>
<td>2.8</td>
<td>3.0</td>
<td>0.2</td>
</tr>
<tr>
<td>2.6</td>
<td>2.6</td>
<td>0</td>
</tr>
<tr>
<td>3.3</td>
<td>3.5</td>
<td>0.2</td>
</tr>
<tr>
<td>2.8</td>
<td>2.7</td>
<td>-0.1</td>
</tr>
<tr>
<td>1.9</td>
<td>2.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

\[ \bar{x} : 3.33 \]
\[ S.D. : \pm 1.01 \]

No significant variations of the concentration of calcium, zinc, and copper in serum were obtained; however, a significant drop in the iron concentration was detected, as it is represented in Figure 22.

5.3. DISCUSSION

a) Anthropometric variables

The problem of energy balance is rather complex and the homeostatic control for its regulation has not been yet clearly defined. It is difficult to explain how some individuals can maintain a constant body weight with a wide range of energy intake. Many studies about experimental underfeeding or overfeeding have shown a wide range of variations of body weight (Gulick 1922, Miller and Mumford 1967, Apfelbaum et al. 1971, Garrow 1978, Norgan and Durnin 1980). Due to this variability, terms such as "specific dynamic action", and "luxusconsumption" have arisen in the literature (Neumann 1902). It is more frequently
Fig. 22 Changes of Fe Ca Zn and Cu concentration in 15 children during a fiber diet
used, nowadays "dietary induced thermogenesis" proposed by Miller et al. (1967) to describe the increase in heat production associated with foods.

Several authors (Miller 1978, 1979, Garrow 1978, Bierich 1978) do not accept the impact of physical exercise as an important tool in the treatment of obesity. Our results indicate significant variations of body weight and in the body composition with the four therapeutic regimes (Tables 10 and 11). Those groups on the exercise regime showed slightly greater total body mass reductions than the other ones, although it was only significant when comparing groups I and IV, and II and IV in females, and I and IV in males. As it may be appreciated, for an adequate assessment of the influence of exercise, only groups I and II, and groups II and IV are able to be matched, because they only differed with each other in the training programme since the diet given was the same. Therefore it is only possible to say that the difference between groups II and IV in girls is due to the training. However, regarding the variations of TBW in both sexes the F ratios were highly significant and the pairwise comparisons yielded clear differences due to exercise. This finding supports our previous report (Peña et al. 1980a) in which the importance of evaluating the variations in body composition was stressed; firstly, because when exercise is involved, it may influence more upon the body fat than on the whole body mass; second, because the aim in the treatment of obesity is the reduction of fat since this is the compartment involved in its definition.

Another element which reinforces the evaluation of the composition of the body was demonstrated when the d%IW/HA was analyzed. In boys no differences among groups appeared significant. In girls this indicator yielded a bit more information but the differences were not as sharp as with body composition determinations (Figure 20). Indeed, the exercising groups significantly reduced more fat and spared more lean body mass than the other groups did. It had been noted (Rath and Slabochova 1964, Slabochova 1967, Rath 1970, Sonka 1978), that a positive nitrogen balance is achieved when obese patients join exercise
programmes with or without dietary restriction. Moreover, of essential importance have been the investigations about the influence of exercise on fat mobilization (Issekutz and Miller 1962, Gold et al. 1963, Pařízková and Stanková 1964, Issekutz et al. 1965, Leusink 1972, Pařízková 1977) that could explain the reduction of the body fat, as we have already mentioned.

With regard to the treatment of obesity, Mayer (1968) recommends a detension of body weight rather than a reduction of it since he considers that the child gradually reaches its appropriate weight. When Pařízková (1977) commented this statement, she considered that this was not applicable in cases of extreme obesity; furthermore, it is also very difficult in those children near to or at puberty because they are very close to their final stature.

Some authors applying different exercise regimes have obtained a greater drop of LBM than in our results (Balabansky 1979), or no changes, or even an elevation of the body fat (Björntorp et al. 1970, 1973, 1977). Among the possible causes of these findings could be involved the cellular type of obesity—a matter not studied in our patients—the magnitude of dietary restriction, and the physical training programmed. Of prime importance have been judged by Pollock et al. (1980) the following recommendations also used by us: the mode of activity (Pollock et al. 1975), the initial level of fitness (Shephard 1968, Crews and Roberts 1976), a frequency of five times a week, the intensity, and the duration of training. These suggestions may have played an important role in our results.

In order to know the influence of a high fiber content in the diet, groups I and II with the same exercise programme and different diets were compared, as well as groups III and IV, also with different diets but without training.

Those groups consuming more fiber exhibited greater but not significant reductions of body weight, %BF, BFkg, and also LBM kg than the other ones, therefore, only a tendency was found.

Undoubtedly, the fiber in the diet is of importance in human nutrition, although the majority of its effects have been
hypothesized from epidemiological observations. Some of its properties and few experiments carried out point to the beneficial effect on health and on the prevention of a great number of current diseases (Trowell 1971, 1978, Van Itallie 1978, Burkitt 1979).

The term dietary fiber is a generic term for all structures of plant foods that are not cleaved by human digestive enzymes (Trowell 1973) but there is no agreement among analysts concerning the methods of analysis (Trowell 1976). Possibly, there exist individual differences with respect to the digestibility of some fibers in the intestine related with the gut microorganism. Hence, several factors interfere with the interpretation and comparison of results.

Speculating about the tendency found by us in the results, in which also a slightly greater reduction in LBM was seen, we could mention that in foods with a high fiber content the total heat of combustion is greater than the actual metabolisable energy.

Although in the table employed the digestibility was taken into consideration, the variability and error of the calculation is practically unavoidable. Furthermore, the other possible mechanism suggested by Heaton (1973), Trowell (1975), and Van Itallie (1978) (already described at the beginning of this Chapter) could play some role. It would be of interest to know if with longer controlled studies the variations of the anthropometric parameters become apparent.

b) Physical fitness

When a physical exercise is done a great number and varieties of mechanisms are switched on. The ability of the organism to establish the adequate interplay among the systems involved in order to maintain the various internal equilibria depends on the fitness of an individual. (Darling 1947, Leusink 1972). When the exercise is habitually performed a lot of adaptive responses take place and biochemical, functional, and structural changes may occur. We have already commented in Chapter 3 on the effects of habitual physical activity upon the organism.
We have studied the variations of the aerobic capacity—through the PWC\textsubscript{170} and \(\dot{V}O_2\max\)—after the four different treatments.

These parameters improved significantly within each of the regimes excepting for their absolute values in group III of males, although the relative values were all significant. This fitness enhancement may be explained in the non-exercising groups by the reductions of body weight and namely body fat, and therefore a reduction in the non-recorded extra load when performing an exercise.

The differences in the enhancement of the PWC\textsubscript{170} among groups was manifested with the F ratios obtained in both sexes. The influence of the four week period of training in group I and group II yielded significant t values when comparing to group III and group IV, respectively; on the other hand, when the effect of the fiber in the diet was tested no significant difference was obtained.

In the girls the relative values (PWC\textsubscript{170}/BW and PWC\textsubscript{170}/LBM) followed the same trend. In boys only a significant difference was obtained between groups II and IV. Nevertheless, the mean increments were greater in group I than III but the values were not significant. The significant response in girls could be ascribed to the fact that the training that they received was relatively harder than that of the boys, considering the different adaptability of vegetative function (Pařízková 1977) as well as the differences in the lean body mass proportions (Peña et al. 1980b).

With respect to \(\dot{V}O_2\max\), excepting group III of the boys, the rest of them exhibited improvements in this variable. The relative values, on the other hand, showed significant elevations within all the groups. Moreover, as reported by Pařízková (1977) this maximal oxygen uptake was obtained after a greater work load than before starting the treatment. However, differences among the four groups were not detected either in boys or in girls.

It is interesting that among-groups differences were only
seen in the increments of $FMC_{179}$ —absolute and relative values— while in the $V_{O_{2\text{max}}}$ were not found. This finding may be due to that the former parameter is assessed during sub-maximal work loads, where the aerobic process predominates and the influence of training could be of greater importance. Otherwise, $V_{O_2}$ was measured only at the maximal load, where the aerobic and anaerobic processes are overlapped (Margaria et al. 1965) and could mask the real effect upon aerobic endurance.

The performance enhancements on those groups involved with physical training could be explained by three mechanisms: a) improvement of the adaptative function, b) development of better skills for cycling, and c) the one already explained for the non-exercising groups: the reduction of the body weight and body fat, and consequently a reduction of the work necessary to move the legs; but to define the contribution of each of the mechanisms proposed is extremely difficult. Again, it is evident the necessity to include training or sport programme in the treatment of obesity, our results support this statement. Moreover, the aerobic capacity of the obese is able to be enhanced with systematic physical activity; but to ensure it, is of great importance the motivation of the patient and the reliance to be given at the beginning of the treatment, as it has been discussed in the preceding Chapter.

We must underline that our experimental design has several controvertible points. Although we try to homogenate the distribution of children among the four groups regarding chronological age, bone age, and pubertal status, the size of the sample does not permit us to avoid bias due to the individual characters. Theoretically, if all the subjects could adhere to the four regimes it seemed that the individual component apparently disappears; but also several reasons are disputable:

If one-week period for each treatment would be considered it is a very short time in order to assess reliable variations of body composition and fitness. Otherwise, longer periods under ward conditions surely do not make any benefit to the child from the psychological point of view, and for research purposes it is ethically rejectable. Moreover, it is known that
neither the reduction of body weight nor the reduction of body fat have a linear distribution (Bray et al. 1972); hence, the variation after the first mode of treatment will differ from the following modes, in other words, a methodological bias would be introduced. Besides, this study is only possible to be done under careful observation, and with an accurate control of the diet and the exercise programme.

c) Fiber, fat, and minerals

It was our purpose to increase the fiber content moderately, from high fiber foodstuffs commonly consumed, such as cereals, fruits, vegetables, legumes. We avoid the use of bagasse, wood, or artificial fibers (Jeffrey 1974, Jenkins et al. 1976) because these are unusual sources and could imply toxicological risks.

Taking into account the possible nutritional implication of dietary fiber on fat absorption, we performed a Van de Kamer test which yielded no differences. Cummings (1978) in studies performed in volunteers who consumed 45 g per day of fiber during three weeks have seen an increase in the fecal fat excretion, although it was not considered as a pathological rise. Other authors (Walker 1976, Kay and Truswell 1977) reported similar findings, but the mechanism remained unclear.

Regarding mineral absorption, since a long time ago it is well known that fiber could produce a calcium and iron negative balance. Berlyne et al. (1973) reported osteomalacia caused by high consumption of unleavened bread. He ascribed this feature to the phytic acid content but more recent studies (De Lucas and Bugg 1975) provided evidence that calcium binds to D-glucoronate residues, and that fiber may indeed bind calcium (Reinhold et al. 1975, Branch et al. 1975). The magnitude of the impairment of calcium absorption depends primarily on the amount of fiber and also on the type of it. With the diet employed no differences were seen but as have been shown in Figure 21, a significant reduction of iron was obtained. Although this decrement is not so severe, supplementation of this mineral shall be indicated. The participating mechanisms are not well determined, phytic
acid is again incriminated (Bjorn-Rasmussen 1974, Hallberg et al. 1974, Jenkins et al. 1975), but these findings clearly need further study.

Other two trace elements, which have earned recently clinical identity, have been also stressed that fiber may play a role in their deficiency (Prasad et al. 1961, 1963, Hambidge and Walravens 1976, Reinholt et al. 1976). Again, with a fiber content of nearly 15-20 g no negative balance has been reported, yet. We consider of importance, however, that the source of fiber for childhood should be from natural foodstuffs. A monthly follow-up of the serum iron concentration should be done, and iron supplements should be prescribed.

d) Summing-up

Unfortunately, very few workers include these two important aspects--body composition and physical fitness--which reveal in some way structure and function, respectively, in the follow-up of obese patients attached to any treatment. We have used determination of %BF, BF(kg), and LBM(kg) which permit a quantitative assessment of the variations of these compartments and enriched singularly the information given by the whole body mass measurements. In this way, we have shown that it is possible to evaluate with more reliability the influence of diverse variables involved in the treatment --e.g. fiber and exercise--, in other words, a greater possibility for qualifying treatments more objectively.

It is obvious from these results that the information yielded by BW and IW/AN are not enough for the adequate understanding of the changes that are taking place on those individuals under treatment.

The inclusion of exercise in the treatment produced a greater reduction in BF, a spare of LBM, and better improvements of fitness, especially at sub-maximal work load as we have obtained with the elevation of the $\text{FWC}_{170}$ in both sexes. For instance, exercise is of primary importance in the therapeutic approach of obesity. What it is necessary is to promote a strong motiva-
tion to avoid the drop-out of the patient. The increasing of fiber in the diet is a relative new approach in the treatment of several entities including obesity. We did not demonstrate any significant advantage upon the parameters studied, although a trend toward it was seen. The amount of fiber given to our patients did not affect either the fat absorption, or the serum concentration of Ca, Zn, and Cu. However, we suggest to give additional quantities of iron during this treatment, specially when the treatment will be prescribed for longer periods.

We should also stress that all our patients and their parents received nutritional advice and psychological support in order to change wrong nutritional habits and to encourage in physical activities. These aspects although were not included in the text of this dissertation are without any doubt fundamental parts in the comprehensive approach of the treatment of obesity.
Chapter 6

FINAL COMMENTS AND CONCLUSIONS

In our work we introduced two approaches which permit to characterize and assess the morphological and functional status of the subjects studied. These approaches were the determinations of the body composition and physical fitness of the individuals.

In a selected sample of Hungarian obese children several anthropometric measurements were studied. The stature of 64% of the obese girls and 50% of the obese boys were found to be at or above the 75th percentile of the data obtained in the cross-sectional growth study performed in Kőrmend, Western Hungary by Eiben (1978).

This "tallness" tended to decrease from 13 years old on; and in girls at age 14 no significant difference appeared. Many authors have stated that obesity promotes high stature, since a great proportion of obese children exhibit heights at relative high percentiles; however, those findings do not allow to draw any conclusion. Indeed, two questions arise: Are the tall children more prone to obesity? Or a positive nutritional balance accelerates the process of physical development? Johnston and Mack (1978) have suggested that the excessive weight gain in the first year of life seems to be more closely related to increased stature than fatness itself during adolescence. Furthermore, in the majority of the cases we did not detect any sign of early appearance of the secondary sexual characters nor advanced bone age. Indeed, growth and development are influenced by the interplay of many factors such as
heredity, ethnic origin, climatic conditions, and nutrition, among others; and some caution must be exercised in interpreting these results. The most widely used indicator for diagnosing and quantifying obesity in a clinical setting is, by far, the percent of the ideal or expected weight for the actual height of the individual (IW/AH). Although this indicator could yield some information in population or subpopulation studies, to use it in the nutritional assessment of an individual could lead to serious misinformation. Some authors judge that there is not any other alternative to diagnose obesity but measuring fatness, and many studies have focused how to discern between a slight obese from other subjects whose overweight is due to a greater lean body mass with an acceptable proportion of body fat, in other words, the so-called marginal cases; subtracting importance to the measurement of fatness in the clinically evident obese. However, we have demonstrated great discrepancies even in the unquestionable obese patient, regarding IW/AH. For instance, we detected children with the same body weight and height --hence, the same IW/AH--differing grossly in their percent of body fat. Also, we have found patients whose IW/AH figure is greater than other obese whose fat is lesser; that is to say a heavier boy could be less obese than the "lighter" one. On the other hand, when the obese children were attached to different therapeutic regimes, e.g. including physical exercise, no differences among the groups of boys were found in the reduction of the IW/AH, however, when assessing the variations of body fat significant differences became clearly apparent among the exercising groups and the non-exercising ones. Another advantage was the possibility to identify the sparing of lean body mass that took place when exercise was involved. These reasons ratify the importance of the determination of the body composition in individuals with obesity.

Recently it has been described in our department of nutrition, by Amador et al. (1975) a new and simple indicator of the nutritional status which has been proved to reflect closely the relationships between adiposity and lean body mass. This indicator--the Energy/Protein Index--has been correlated with dif-
ferent parameters; therefore, we considered important to study its correlation with %BF, yielding highly significant r values. This result confirms the assertion to be used as a measure of adiposity; and also gives information about the relation between adiposity and lean body mass which explains the difference found among the subgroups studied. This index was also correlated by us with a fitness parameter, $\text{PWC}_{170}$ absolute and relative values, yielding significant negative r values. Since E/P reflects in some way the nutritional status and body composition, the relationship found between the index and fitness could be explained considering that fitness is a multifactorial biological feature.

The evaluation of the physical fitness has become a very useful tool for a comprehensive assessment of health or its impairment. We have studied the aerobic capacity of three selected samples of Cuban boys: obese, non-obese, and specially trained boys who practice systematically swimming for at least 2.5 years.

Significant differences among groups were seen in the $\text{PWS}_{170}$ and $\text{VO}_{2\text{max}}$. The swimmers exhibited the highest scores and no differences appeared between the non-specially trained non-obese boys (regarded as controls) and the obese ones. However, according to the recommendations of the IBP, these variables were referred to mass units (BW and LBM) as a good basis for standardization; then, the three groups differed significantly from each other and the obese attained the poorest results. Furthermore, the negative r value in the regression study of log $\text{PWC}_{170}$ with %BF confirms that excess of fat exerts a negative influence upon fitness.

An attempt was done to know how much oxygen the boys consumed per kg-m of work performed during one of the sub-maximal work loads. The swimmers and controls did not differ in their results significantly, but the obese consumed significantly more oxygen per unit of work. This fact has been interpreted by many authors as an alteration of the work efficiency of the obese subjects. With this in mind, we assess in a smaller sub-sample
of obese and non-obese boys the oxygen consumed at three submaximal loads of small magnitude to ensure sufficient exercise points of aerobic work. At each work load, the \( \dot{V}O_2 \) of the obese was greater than that of the controls, and when the regression lines were calculated they showed a parallel displacement, since the slope was practically the same and only differed in their intercept. This finding shows that the rate of variation of the steady state \( \dot{V}O_2 \) was the same at each work load. We ascribed this feature to the constant load—not recorded in the ergometer—due to the greater leg mass while pedalling. Thus, the handicap of the obese when performing a physical activity is namely due to the excess of fat rather than actual impairment of work efficiency.

As it has been shown, the aerobic power of the swimmers was the highest among the groups. They were able to perform more work, and showed, according to the \( \text{PWC}_{170} \) and oxygen pulse, a better cardiorespiratory adaptation to exercise, enhanced fitness and resistance. This superiority could be due to the influence of the habitual training and/or to initial selection, in fact from cross sectional comparisons the factor of selection is unknown and can play an important role in the best results.

The three groups of boys increased significantly their blood glucose after the maximal exercise, but the significantly highest among them was the group of trained boys. This finding is in concordance with previous reports suggesting that glucose release from glycogen stores could be enhanced with training (Rowell 1971). The blood lactic acid also increased significantly after work in all groups, but the difference among them was not significant, although the highest increments were seen in the swimmers.

Previous studies have demonstrated a decreased sensitivity to lipolytic stimuli (to caffeine among them) in obese subjects. Considering that the improved performance corroborated in athletes with caffeine has been ascribed in part to its lipolytic effect, we studied the influence of caffeine upon \( \text{PWC}_{170} \) and \( \dot{V}O_2 \text{max} \) in obese and non-obese subjects. Both in-
creased significantly these parameters after the ingestion of caffeine, moreover, the magnitude of improvement did not differ between them. The better performances obtained could be a sort of aid at the beginning of training programmes in those grossly obese patients who are extremely handicapped when performing physical exercise. Nonetheless, the most important action to be carried out is to motivate adequately the patient and if this measure fails, then the administration of caffeine should be considered.

Another aspect included in this study was to evaluate the variations of the body composition and aerobic capacity of obese children joining to different therapeutic regimes during a 4-week period. The four regimes had the same energetic intake (4.180 MJ), and consisted in: I: Fiber diet (15 gr of crude fiber per day) and a special training programme. II: A diet with an "average" fiber content (5-6 gr per day) with the same training programme. III: The same diet as I with no training, and IV: The same diet as II also without training.

Significant decrements within each group in BW, IW/AB, body fat (percent and absolute values) as well as in LBM were obtained. When the groups were matched according to diet, in order to assess the influence of exercise we have not detected clear differences in the reduction of BW between them; however, those who exercised reduced approximately twice the %BF than the non-exercising ones did. Also, the reduction in kg of BF was significantly greater and a significant sparing of LBM took place.

The aerobic capacity increased significantly after treatment within all groups excepting in group III of boys in which the elevation obtained was not statistically significant. The enhancement of the PWC_{170} was much more appreciable in the exercising groups. We ascribed this finding to the greater reduction of fat obtained by them, to the influence of training on the development of better skills, and the improvement of adaptative functions promoted by exercise. Differences among groups in the VO_{2max} were not seen.
The structural and functional variations achieved in our patients show the important advantages of including physical exercise as part of treatment.

Prior to 1975 there was almost no mention of the importance of fiber in human nutrition. Afterwards, its role in the prevention of several diseases, including obesity, have been suggested. We increased the fiber content to 15 gr per day from natural sources. The groups consuming fiber diet, when matched to the presence or absence of exercise, showed a trend toward greater reductions in body weight and body fat, as well as better improvements in the aerobic capacity, although the differences among groups were not statistically significant. Probably if longer periods were considered, these differences become apparent.

It was proved that the quantity of fiber ingested did not affect fat absorption, tested through a Van de Kaner test. Furthermore, the concentrations in serum of calcium, zinc, and copper did not vary significantly; however, a significant reduction in the serum iron level was detected.

We want finally to briefly summarize some of the features that we expect to have made apparent as a result of this study:

1. The use of the percentual value of ideal weight for the actual height in measuring obesity leads to serious misinformation even in the clinically-evident obese subjects, hence the body composition should be assessed.

2. The Energy/Protein Index reflects well fatness since it is significantly correlated with body fat percent. This index also correlated well with the PWC170.

3. This study confirmed that obese children have a relative lower aerobic capacity than non-obese, but this impairment is namely due to the greater fat mass rather than an alteration of work efficiency. Furthermore, significant improvement in the aerobic capacity was found after a 4-week period of slimming treatments.

4. The trained boys exhibited the highest indices of cardio-
respiratory adaptation, though the energy cost of work did not differ from non-trained lean boys.

5. Caffeine has been found to improve significantly and in the same magnitude the aerobic performances of obese and non-obese boys.

6. This investigation contributes to support the importance of the study of body composition and physical fitness to evaluate different treatments of obesity.

7. A moderate restriction of energy intake with a relative high fiber content associated to physical exercise proved to be the most advantageous therapeutic trial tested in this study.

8. The addition of physical training to a reduced energy intake promoted a greater body fat reduction, a relative sparing of lean body mass and better enhancement in aerobic performance.

9. The evaluation of the fiber content in diet showed a tendency to greater body fat reduction and improvement in aerobic capacity although these findings were not statistically significant.

10. It was proved that a crude fiber content of 15 g per day during 4 weeks did not affect fat absorption. Moreover, the serum concentration of calcium, zinc, and copper remained unaltered; however, a reduction of the iron level was seen.
Several anthropometric variables were assessed in a selective sample of obese children. The importance of the evaluation of the body composition was demonstrated, not only for diagnostic purposes but for an adequate characterization and an objective follow-up of patients attached to slimming programmes.

Obese boys exhibited a relative poor aerobic capacity, namely when comparing to controls and specially trained boys. This impairment is likely due to the excess of body fat rather to an alteration in the efficiency of work. On the other hand, the trained boys obtained the best performance characterized by a better cardiorespiratory adaptation.

Significant improvements of aerobic performances were seen after the ingestion of caffeine in obese and non-obese boys. Moreover, the magnitude of this improvement did not differ between them.

The variations in body composition and physical fitness were studied in four groups of obese children joining to different therapeutic programmes. The best results were achieved in the group following physical training and a relative high fiber diet. The positive influence of exercise was demonstrated.

It was proved that a diet with a crude fiber content of 15g per day did not affect fat absorption neither the concentration in serum of calcium, zinc, and copper; however a significant drop in the iron serum level was detected.
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