Energy Balance and Dietary Intake Analysis of Hong Kong Elite Athletes

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Introduction

Far in the early days of the Hippocrates, the importance of the balance between food intake that provided fuel to the body (energy intake) and physical activity for health was recognized.. Optimal nutrition and energy intake, besides promoting well being, most effectively improve exercise capacity and performance. (Olympia 93). The consensus statement from the Olympia Committee further emphasizes on the importance of an adequate diet, in terms of quantity and quality to maximize performance. The major objectives of sports nutrition thus focused on proper nutritional maintenance and development during training, pre-competition preparation and nutrition during competition.

Recent advances in the scientific research aims to make definite recommendations of the nutritional needs of athletes to optimize performance. (Position paper of ADA 87, Final Consensus statement 1991). However, in order to put foreword dietary recommendation confidently, it is important that the observations on the actual nutrition requirement and dietary practice of the athletes are assessed carefully and continuously. The evaluation will help to accurately determine the nutritional needs of each individual athlete at different period of the activity. This study aims to assess the overall nutritional adequacy of the athletes intake by studying the energy expenditure (energy requirement) and the self-selected dietary intake of the athletes.

SECTION I

Energy assessment in elite athletes

Adequate nutrition, including energy balance, in the athletes is important for nutrition maintenance, physical development and maximizing sports performance. (Consensus statement 1991). Studies have reported the influence of exercise and diet on total energy expenditure in individuals and groups (Van Zant, S. 1992). Energy cost data were derived for different sports and at varying work intensity by many scholars, based on the original work of Astrand and Rodahl 1977. Energy expenditure in individual athletes, even within the same sports, obviously differs depending upon the duration, intensity and frequency of the exercise. Observations have indicated differences in energy expenditure exist in different condition or caliber level of the competition in the same group of athletes. Differences in energy expenditure of athletes were observed during simulated competition and competition of lesser caliber and significance, than those during actual World Championship and Olympic competitions(Hagerman & Falkel 89). The importance of assessing individual sportsman for their specific energy expenditure thus becomes a challenge for those interested in providing optimal energy. Different scholars (Harris and Benedict, Durnin 91, Pavlou KNN. 93) have attempted to develop equations to calculate the daily energy needs for without true accuracy or needs further validation from free-living conditions.

Thus, correct estimation of energy expenditure in the athletes is important for the assessment of nutrition adequacy in this population. Dietary recommendations can be based on the combination of knowledge in energy input and output, it will provide useful guidelines for nutrition counselling and the evaluation for any necessary change in dietary behaviour so that optimal nutrition can be met. This paper presents the pioneer effort in the measurement of energy expenditure and nutrient intake of elite athletes in Hong Kong.

Techniques in the measurement of energy expenditure

The joint report of a FAO/WHO/UNU committee Expert Consultation on Energy and Protein requirements (1985) recommended that wherever possible estimates of energy requirements should be based on measurements of expenditure rather than intake. It has been known that energy in individual sportsman differs upon the type of sports, exercise frequency, intensity and duration.

1. Direct calorimetry
   - considered as the most accurate means for the measurement of energy expenditure where direct heat output is measured in an enclosed chamber. Accuracy is reported to be within 1-2%. Subjects have to be confined in metabolic chambers for continuous measurement of heat output /gaseous exchange. (Warwick 88).
2. Indirect calorimetry
   - the measurement of oxygen consumption and carbon dioxide production, on the assumption that heat production is consistently related to gaseous exchange (Ferrannini 88). It consists of the need to rely on a number of assumptions in the calculation of TEE

Heart-rate method

As the above two techniques are not practical to measure energy expenditure in real life, therefore heart rate method was chosen to assess the subjects energy expenditure in this study.

Procedure:

a. Subject calibration

Individual calibration of the relationship between heart rate and oxygen uptake is important with the facts that the slope of the relationship between heart rate and oxygen uptake varies between persons depending on their endurance capacity

b. Calculation of energy expenditure from heart rate record

-TEE includes the energy costs of basal metabolism (BMR) and physical energy which is dependent on the duration and intensity of physical activity.

- In the estimation of daily energy expenditure of individuals, it is necessary to have a measurement of BMR, in addition to a detailed time use and activity description. However, in the absence of such measurement, the Schofield equation **(Appendix I)** is used in the tabulation of BMR in the minute-by-minute heart rate method as validated by Spurr & Prentice 1988

Validation of heart-rate method

The validity of using minute-by-minute heart rate method in the estimation of energy expenditure is validated by comparison with whole body indirect calorimetry.(Spurr 1988 and Ceesay SM 1989)

Recent study has also validated the FLEX HR method against doubly labeled water method , indicating a close estimation of the TEE of population groups. and doubly-labeled water method (Livingstone & Prentice 1990 Am J Clin Nut) That this method can closely estimate the TDEE and energy expended in activity (EAC) of even small (n=4-6) groups of subjects, giving a maximum error of TDEE for individuals of +6.8% and -2.7%. (Spurr & Reina 88).

Better estimates in activity energy is expected in active individuals than sedentary subjects since the average heart rate while awake is on the active portion of the calibration curve where reliability is much higher. The estimate may be further improved by repeated measurements over several days. (Spurr & Reina, 1989 Proceeding)

Subjects

28 subjects were recruited, including 19 athletes (age 15-29) and 8 normal subjects (age 19-24 yrs) were also included in the study for comparison purpose.

Athlete subjects were recruited on the basis of being a Hong Kong team member and have represented Hong Kong in international and local competitions. Among them are world-ranked athletes from sports such as windsurfing, badminton etc. While normal subjects are all office workers and did not involve in any kind of systemetic physical fitness training.

Since many of these elite athletes do train daily, no attempts were made to change their normal training schedule for these athletes, instead light training days with short exercise periods are often classified as 'rest day' for these elite athletes. The physical characteristics of these subjects are presented in **Table 1.**

There was no significant difference between the athletes and normal subjects in body weight at the beginning of the study, for both sex. There was also no significant differences in body weight of the two groups for both sex. Thus, the athletes group and the normal subjects were quite similar in weight and body composition.

Experimental protocols for individual Subject calibration

Each subject was individually calibrated to establish oxygen consumption (VO2) and heart rate (HR) relationship. The calibration was done within 7 days from the actual heart-rate recording period. The Gould 2900 was used for measurement of VO2 and VCO2, and establishing the relationship between heart-rate and energy expenditure.

The calibration procedure were performed in two protocols. One involved the simultaneous measurement of heart-rate and VO2 on lying, sitting, standing positions. The average of all of these measurements was used as the resting energy expenditure (RMR). The other protocol used a treadmill exercise with increasing speed and grade to assimilate activity motions. The subjects began walking at 3 mph, 5 mph, running at 7 mph, 7.5 mph and at an elevated gradient of 2.5%, or until the subject's heart rate increased to approx 180 beats/min. At each level of activity, the activity period was done for 6 min. preceded by a 5 min. walking rest at 2.4 mph. Measurements of HR and VO2 were made during the last 3 minutes of the activity period when subjects were assumed to reach a physiological steady state. The testing protocol is presented in **Table 2.**

Respiratory gas and heart rate analysis

During the calibration procedure, all analyses of expired and inspired air were performed using the Gould 2900 (Sensormedics, U.S.A.). The apparatus continuously measured pulmonary ventilation, the expiatory fractions of oxygen and carbon dioxide, and programmed to provide data on ventilation, oxygen uptake, carbon dioxide production, respiratory exchange ratio and energy expenditure. For safety and accurate recording of heart rate, heart rates were taken from an ECG monitor (Gould, U.S.A.) continuously. Heart rate recorded on ECG monitor were also simultaneously checked with the heart rate reported on the Polar heart rate recorder to ensure accurately of the two readings. Data were collected every 20 seconds throughout each protocol. A typical calibration curve for an athlete is shown in **Appendix II.**

Heart-rate recording equipment for study period

The PE4000 heart rate recording system was used for recording heart rate . It consists of a belt weighing 20g worn at the chest and a watch worn at the wrist (Polar Electro, Inc., Hartland, WI, U.S.A.) . The device has a digital component for recording the heart rates 1 minute intervals and has a storage capacity up to 34 hours. At the end of the study periods, the hart-rate records were retrieved via an interface unit and PC for which an additional program was written to compute TEE from HR. **(Appendix III).** The device does not interfere with subjects' daily activity and is able to measure activity patterns of subjects.

The establishment of individual heart-rate and energy regression formula

According to Spurr , RMR was calculated as the mean of all the resting values of VO2 obtained during the calibration procedure and expressed as kcal/min. There are two ranges of heart rates: rest and activity. A critical heart rate is determined above which the slope and intercept of the calibration curve will be used to calculate VO2 and below which RMR will be used as estimate the energy expenditure for the minute in question. The critical HR is referred to as FHFLEX. The FHFLEX is calculated as the average of the highest resting and the lowest exercise HR. If the observed HR during the studied period is below FHFLEX then RMR is used for the EE, if above the exercise curve is used to calculate VO2 and energy expenditure according to the readings obtained by Gould 900. Each individual subject was then able to obtain a specific HR and energy expenditure data pattern using linear regression analysis, and calculations on each individual heart rate record were done by using computer software . As for sleep energy,

- The prediction formula for BMR from Schofield was used.
- Study in whole-body indirect calorimetry indicated that prediction formula of Schofield BMR may overestimates RMR during sleep by an average of approximately 2% (measured: predicted values, mean, 1.02, s.d. 0.09, range 0.82-1.19), however, due to the significance in activity energy, the calculation of total energy expenditure makes the error becomes negligible. (Goldberg et al 1988).

The recording of activity/exercise and heart-rate profile

The assessment of energy expenditure in the athletes was done in the Spring months with an average temperature of 23 °C. The objective was to obtain 3 representative estimates of 24-h energy expenditure during the measured period, covering training and non-training or light-training days in the athlete population. Each subject was fitted with the HR recorder early in the morning, and worn continuously including sleep hours, but except when taking a bath. The subjects were advised to return to the centre for the transfer to data into the computer within 36 hr. An unsupervised self reported activity record was kept by the subject simultaneously to record exercise, free-time (walking, sitting, typing etc.) and sleep hours. To provide a better reflection of habitual performance in these athletes, no attempts were made to change the training or resting schedule of these elite athletes. Accuracy of activity recorded were checked against HR record pattern to ensure accuracy of reported exercise/training pattern.

A typical HR pattern and activity record of an athlete is presented in Appendix IV.

Results & discussion

Within the athlete population, one can observed a wide range of daily energy expenditure (and thus energy requirement) for the different sports. Ranging from the lower energy expenditure of 2820 kcal per day for the gymnasts to the highest energy expenditure of 5689 kcal/day for the windsurfers. Energy spent on exercise also differs widely from 769 kcal/day of the gymnasts to 1551 kcal/ day for the soccer players. This variation in energy cost of exercise in different exercise is obviously a reflection of the differences in intensity, duration, exercise type etc. of these training. The wide standard deviation of each individual sport (35.5%) is also a reflection of individual differences and wide variation from day-to-day even in the same sports as reported in other observations.(Hagerman 92). **(Table 3)**

There is no significant difference between male and female athletes in the % of energy spent in exercise, amounting to 26.4- 32.8% of the total daily energy expenditure **(Table 4).** Energy expenditure in exercise days is also significantly higher than energy expenditure in rest day in individual athletes. This additional energy expenditure from training reflected the importance of extra energy requirement of the athlete population as compared to sedentary controls.

Male athletes significantly spend more energy on exercise days than female athletes, and significantly has a higher daily energy expenditure than female athlete(**Table 5).**

Female athletes had significantly higher energy expenditure than normal subjects. However, on rest days, female subjects have similar energy expenditure whether they are athletes or sedentary controls the result of which may be a reflection of the similar BMR in active and non-active subjects (Bingham 89) (**Table 6**).

On rest days, surprisingly normal male subjects spend more energy than male subjects, This can be explained by the fact that athletes do spend most of the rest days lying, watching television, sleeping etc. while two of our office male subjects are messengers and walked extensively during working hours. This may be part of the reason why the overall energy expenditure of the male athletes did not differ significantly with the normal male subjects. Overall male subjects did have a significantly higher energy expenditure than females.

SECTION II

Nutrient intake in elite athletes

Studies were conducted to estimate the relative contributions of carbohydrate, fat and protein to exercise energy, especially endurance activities. The relative contributions of these energy sources to the total energy pool is dependent on:

1. intensity , type and duration of activity
2. nutritional status and diet composition
3. training status of the athlete

Proteins

Recent research have concluded that carbohydrates are the preferred fuel for high intensity anaerobic exercise, fats for very low intensity aerobic work, and proteins contribute only minimally at any exercise intensity (Hasson, S.M. 1989, Hargreaves 91). Protein oxidation may account for only 5-10% of the total energy requirement in exercise (Lemon 93).

Carbohydrate

Sports scientists have repeated demonstrated that carbohydrates are important substrates for contracting skeletal muscle and carbohydrate availability (muscle, hepatic, blood) is essential for heavy training and athletic performance.

Muscle glycogen concentrations in well-fed and rested endurance athletes is reported to be almost two times more than sedentary counterparts, ranging from 140-230 mmol glucosyl units.kg^{-1}ww, and also affected by carbohydrate content of the diet and the training status. (Costill 88, Hargreaves M. 91).

Effect of a high carbohydrate diet

That a high carbohydrate diet delay time to exhaustion in endurance exercise (up to two folds) as compared to a normal mixed diet and a diet of fat and protein (4 folds). (Christensen and Hansen 1939).

The higher the initial muscle glycogen stores, the longer the endurance ability of the subject . With an initial glycogen content of about 100 mmol/kg w.w., observed that subjects could tolerate a 75% VO_{2max} work load for 115 min. When muscle glycogen was reduced to 35 mmol/kg by a low-CHO diet, a 75% work effort could be sustained for only 60 min. A 3 day CHO-rich diet resulted in a muscle glycogen content of 200 mmol/kg and a subsequent work time to exhaustion of 170 min. (Bergstrom et al 67)

Classical studies on carbohydrate loading procedure include the studies by (Bergstorm and Hultman66) and Sherman et al (81). Muscle glycogen stores are reduced during prolonged heavy exercise. Replenishment can be completed, and even to a higher level (supercompensation), by consuming a diet high in carbohydrate for 3 days prior to competition, along with a reduced training volume. (Sherman et al 81)., an accepted means of carbohydrate loading without the traditional 3 days of low carbohydrate diet.

Carbohydrate needs in athletes in recovery

Studies have shown an intake of 500-600g carbohydrate within 24 hours is optimal for restoration of muscle glycogen store after strenuous exercise, allowing delay of fatigue or maintenance of performance on subsequent training. (Costil 81, Ivy 91, Followfield 92). A carbohydrate intake of 70% or more of the daily energy intake has also been proposed for athletes in training.(Devlinn and Williams 1991), though variation in energy intake in athletes may result in a lesser intake. A recommendation of carbohydrate intake based on body weights 8-10g per kg body weight pre day is recommended (Costil 81)

The importance of Carbohydrate diet in training

Muscle glycogen store in repeated days of one hour training is also observed to be lowered . Though an intake of 6-7g carbohydrate per kg per day seems sufficient to support daily resynthesis of muscle glycogen for several days of non-muscle glycogen depleted exercise. Performance can be maintained despite a lower muscle glycogen store as compared to the first day of training, since athletes do not usually work to exhaustion during training. (Pascoe et al 1990).

Higher level of carbohydrate intake during a 4 weeks heavy training (5-10 g per kg body weight) resulted in an increase amount of power outputs and complete more work during training.. (Simonsen et al 1990).

(Costil et al 1988) The ability of swimmers to cope with additional training volume is improved for those athletes able to consume the prescribed amount of carbohydrate (8g per kg body wt) , though no improvements in performance can be observed in groups of athletes with a higher carbohydrate intake (to 12.5g per kg body weight) (Lamb et al 1990).

Adequate carbohydrate intake in training days is thus important to normalize muscle glycogen store, to sustain high-intensity training and to maximize subsequent performance.

Energy needs of the elite athletes

Energy requirement in athletes is reported to higher than in the sedentary population obviously due to the acute (energy spent in exercise) increase output in exercise bout, but also the chronic (raised in resting metabolic rate) effect of chronic training (Poehlman 90, 91), especially matched by a high calorie intake. And that energy expenditure is affected not only by exercise, but also diet composition, sex and body weight of the individual athlete. It has well reported that under-nutrition decreases while over-nutrition increases the thermal effect of activity and feeding (Van Zant 92).

Obviously there are day-to-day variation in training energy expenditure due to differences in exercise duration, intensity etc. However, the assessment will help to make some physiological observation on some typical days of training or resting energy requirement.

To maintain an optimal weight, it is important that the total energy intake is equal to total energy expenditure. Dietary quantity and quality, including energy balance, affects exercise performance and endurance, both during training and at competition.

The optimal diet for sports

The study of dietary intake and practices of athletes have increased in recent years. Dietary surveys of athletes provide important information to understand how much is practiced by athletes. Many dietary studies have reported that the diets of athletes may not reflect present day recommendations for optimal diet (Burke 91, Short & Short 83, Perron 85, Barr 89, Burke 91, 87,88, Loosli 86, Steen, 86, Hawley 91).

Discussion on dietary study

Information available from dietary studies is much greater than that currently available from studies of energy expenditure. (U.K.Panel on Dietary Reference Values).

Dietary record method was chosen in the present diet analysis study because it provides quantitatively accurate information on food consumed during the recording period. (Thompson 94, Hankin, JH.92). However, the potential weakness for inconvenience of weighing all foods consumed is one of the negative factors for inaccuracy in reporting food intake during the study period.

Although discrepancies between energy intake and expenditure in athletes esp. female athletes were often observed, with a daily energy deficit as high as 650-800 kcal per day. (Mulligan et al 90, Hawley et al 91). However, reliability of energy intake result can be checked by comparing the calculated intake to a more objective energy expenditure evaluation (Black et al 91). The assessment in body weight, body fat are thus important to act as an objective evaluation of the energy balance observation.

Method of Dietary Analysis

Dietary intake of the subjects were recorded concurrent with the 3 days of minute-by-minute heart rate energy expenditure assessment. Three days dietary records also offered the advantage of ensuring a more accurate reporting of food consumed, and avoided respondent fatigue over longer periods (Thompson 94, Hankin, J.H. 92). The subjects received detail instructions from a qualified nutritionist for the procedures of food recording. Foods were weighed whenever feasible. Structured and open-ended forms were given to increase the ease and accuracy of recording food intakes (Marr J.W. 71, Pekkarinen, M. 70, Johnson N.E. 82). Photos of mixed dishes were also taken by the subjects to assist in the correct estimation and description of foods consumed.

Subjects submitted their records on a daily basis, during which the nutritionist checked for clarification of entries, and probe for forgotten foods. Nutrient composition was analyzed for energy and selected nutrient contents by a computer program employing database from several food composition tables. The nutritionist coded and entered the data.

Selected vitamin and mineral intakes in relation to the Recommended Dietary Allowances by age was calculated. Macronutrient density related to body weight and energy were also calculated. Comparison was made between the male and female athletes.

Statistical Analysis

The SPSS v.5.0 program was employed for the calculation of necessary statisics and with the significant level set at $p<0.05$.

Result and discussion of nutrient intake

The result of energy and nutrient intake of the athletes are presented in **Table 7-9.**

Energy intake of the athletes

The energy intake of the athletes as a group was significantly higher than the normal subjects ($p<0.05$). The Mean daily energy intake of the male athletes was 4450 kcal per day, and 67.8 kcal/kg body weight. While female athletes averaged 3135 kcal per day, equivalent to an intake of 57.3 kcal/kg. Male athletes thus had a significantly higher energy input than female athletes, which was similar to that observe within the normal subjects, where males also consumed significantly more energy than females.

However, male athletes did not significantly consume more energy than the normal male subjects, while female athletes did consume more energy than female counterpart significantly. Male subjects on the whole consumed significantly more energy than females.

Protein intake of the athletes

The proportion of energy provided by fat, carbohydrate and protein varied within the group.

The mean protein intake of the athletes was 178 and 148g per day respectively for male and female athletes. The protein intake of the male athletes was not significantly different to the female athletes, similar to that observed in the two sex of the normal subjects. The protein intake of athletes as a group was significantly higher than the protein intake of the normal subjects.

Protein requirement in athletes is 1.0-1.4 gm per kg body weight per day (Lemon 91). Mean intake of the athletes have reflected generous intake of protein well above the recommended requirement, due to an increase in energy intake. Similar results are observed in other athlete dietary studies (Burke 87). The result conforms to the observations of exercise scientists that although protein requirements are higher in athletes than in the sedentary populations, however, most athletes would consume sufficient protein as a consequence of their increased energy intake.(Final consensus statement 91).

Carbohydrate intake:

The athletes as a group had a significantly higher carbohydrate consumption than the normal subjects ($p<0.05$). There was no significant difference between the male and female athletes. Unlike the normal subjects, where male consumed significantly more carbohydrate than female.

Athletes from other countries have reported intake of 373g-627g (43-60% of total calories) for men and women 292-428g (48-59% of total calories). (van Erp-Baart et al 1989,; Hawley JA et al 1991; Burke LM 1991). Recommendations from panel of expert agreed that carbohydrate intake should contribute about 60-70%, or 8-10g carbohydrate per kg body weight of the athletes so to maximize carbohydrate stores and optimize performance. (Final consensus statement),

The percentage of energy intake from carbohydrate were 53% and 57% for male athletes and female athletes respectively, less than present recommendations of 60-70% energy from carbohydrate. There were individual instances of even lower carbohydrate intake (as low as 43%). Mean carbohydrate intake was 597g and 450g for male and female athletes respectively. The female athletes were unable to reach the recommended intake of 500g carbohydrate per day required to replenish muscle glycogen store for optimum training, especially for those with strenuous exercise. Tailored diet counselling for these athletes would thus be needed to assess eating behviour and improve carbohydrate intake.

Fat intake of the athletes

Fat intake of the athletes as a group did not differ significantly from the normal subject.
Male athletes significantly consumed more fat than female athletes, similar to that observed in the differences in the two sexes of the normal subjects. while saturated fat intake was also significantly higher in the male athletes. The saturated fats contributed 21.5% to total fat intake.

The mean intake of cholesterol in the athletes was 495 mg per day which is higher than the recommended 300 mg per day for the general population (RDA). The intake was not significantly different from the normal subjects. Cholesterol intake of male athletes was also at the same level as that of the female athletes.

Micro-nutrient intake of athletes

Mean daily intakes of selected vitamins and minerals of the athletes were well above the Recommended dietary allowance. Similar to studies reported similar observation (Burke 87, Hickson 87). Between male and female athletes, the overall nutrient intake was similar. There were no significant differences in the consumption of caffeine, calcium, cholesterol fiber, iron, sodium, thiamin, vitamin A, vitamin C and vitamin E. While in the normal subjects, females consumed higher calcium, and male consumed significantly more vitamin. E and zinc.

In general, deficiency of micronutrient is not expected due to the high calories intake of the athletes. However, in order to meet the additional demand from effects of exercise, such as the increase in energy expenditure and energy metabolism, increase loss through exercise, such a electrolyte loss in urine, sweat,. it is recommended that wide range of food choices should be selected to ensure adequate intake of micronutrients.

The athletes as a whole, consumed significantly more calcium, fiber, iron, riboflavin, vitamin A and zinc than the normal subjects. But intakes of caffeine, cholesterol, sodium, vitamin C and vitamin E were similar to that of the normal subjects.

Despite the acceptable overall group intake, there were instances of marginal intakes among individuals, especially in the consumption of zinc, calcium, vitamin A and riboflavin. The presence if individual differences of nutrient consumption was similar to that reported in other studies (Hickson 87 and Hickson 89).

Of the minerals and trace elements essential for health, particular attention should be paid to iron and calcium status in those individuals who may be at risk. (Final consensus statement 91). Improvements in food choices would be needed to enhance micronutrient intake in some athletes.

Alcohol intake of athletes

Alcohol consumption in the subjects was low. Only 3 of the athletes (two males and one female athlete) had consumed alcoholic beverages in the three day observation period, contributing only 1% of calories to the total calorie intake for each individual. Although no significant differences was observed between the male and female athletes ($p>0.05$), however, due to the small sample size, it was unable to reflect that male athletes did consume more alcohol than the female athletes.

Caffeine intake of athletes

Caffeine intake of athletes was low , with a mean intake of 19.4mg ±21.3 per day. There was no significant difference between male and female athletes, and when athletes were compared to the normal subjects.

<u>Differences between male and female subjects</u>

Disregard of the activity pattern of individuals, it has well been established that there are differences in nutrients consumption and requirement between the males and females (RDA). It was observed that male subjects consumed significantly more fat, calories, protein, saturated fats and vitamin. E. The higher energy consumption is a reflection of the higher energy requirement of the male sex. There was no significant differences between the two sexes in the consumption of other nutrients such as calcium, carotene, cholesterol, fiber, iron, niacin, potassium, riboflavin, sodium, thiamin, vitamin. A, vitamin C and zinc

<u>Result and discussion of energy intake and energy expenditure observation</u>

Physical assessment data showed that there were no significant differences between the weight and body fat status of all subjects at the beginning and at the end of the study ($p>0.05$).

Though daily energy and expenditure on the same day may be different, there was also no significant differences between the total energy expenditure and the energy intake of the athletes after the 3-day study period. The athletes were be able to match the high energy expenditure by raising energy intake. The ability of regulation of energy balance may be a consequence of the physiological need, or that athletes have learned to ingest as much food as possible. (Westerterp KR 91).

Recent studies using doubly-labelled water as a measure of energy expenditure at the same time as 7-day weighed food intakes in adolescents and adults have shown some discrepancies from observed intakes (Livingstone 91, Livingstone 90). They emphasized the need for caution in reliance on any single method of measurement in energy requirement of individuals

Practical Applications

Adequate energy and nutrient intake of athletes are important to meet optimal nutrition preparation for training and competing. The present studies confirmed inappropriate consumption of some nutrients, especially carbohydrate which may jeopardize optimal nutrition preparation for strenuous training in this group of elite athletes. Marginal intake of micronutrients in some individual athletes, especially in calcium, zinc, riboflavin and vitamin A may reflect questionable dietary behaviour. Encouragement to consume a wider variety of foods, especially leafy green vegetables and whole grains, will be important to improve intake of these micronutrients.

The high energy expenditure/requirement of the athletes was met by voluntary food consumption of the athletes in the study period. However, it was observed that the energy output/requirement of the athletes at actual competition could be quite significantly different form that of simulated event or training.(Hagerman 89). Close observations in athropometic measurements, such as weight and body fat, should be practiced to maintenance/achieve desirable body weight, since they are good indicators for energy adequacy of the individual athlete. Additional energy intake will be needed for those who aim to achieve weight gain.

Our coaches and athletes should be encouraged to seek for individually tailored diet counseling so that the very specific needs and dietary problems of each individual athletes can be addressed. Group advice, though may benefit the group as a whole, will not be able to target personal dietary problems for appropriate behaviour changes.

While well planned energy studies with appropriate sampling and equipment will need to be conducted in order to validate the prediction formula of BMR of Hong Kong population, including our athletes. With better technology, research designs and efforts, we hope to understand the specific needs of our athletes, so that optimal nutrients and energy for better health and performance can be provided.

Table 1

(i) Physical characteristics of athletes

Variable	Female (n=8)	Male (n=11)
age (y)	22.6 ± 4.5	19.6 ± 4.6
weight (kg)**	54.7 ± 6.1	65.6 ± 8.8
height (m)	161.9 ± 9.0	173.8 ± 5.8
body fat %	16.6 ± 6.0	5.4 ± 1.6

*:X ± SD

(ii) Physical characteristics of Normal Subjects

Variable	Female (n= 5)	male(n=3)
age (y)	21.6 ± 2.5	21.7 ± 2.3
weight (kg)	47.1 ± 4.2	62.1 ± 6.5
height (m)	158.0 ± 5.1	175.0 ± 7.6
body fat %	20.2 ± 4.2	5.1 ± 1.7

* X ± SD
**Body weight were obtained on a electronic scale (Health o meter, USA), skinfold measurements were determined with a Harpenden skinfold caliper (Quinton, Washington,USA).

Table 2 Exercise testing protocols in athletes

Type of activity/exercise	measurement duration (min.)	workload	grade
lying*	6		
sitting	6		
standing	6		
treadmill walking**	6	3 mph	
treadmill running**	6	5 mph	
treadmill running**	6	7 mph	
treadmill running**	6	7.5 mph	2.5%

*** lying is preceded by a 30 min. rest in same position**
**** activity measurement is preceded by a walking rest at 2.4 mph for 5 minutes**

Table 3
Energy Expenditure of the athletes .*

Sport	Sex	No. of Subjects	Energy Expenditure		
			Exercise Period (KCAL)	Whole Day (KCAL)	Percentage (%)
Windsurfing	F	1	1271.4 ± 1020.6	4221.8 ± 664.3	28.2 ± 18.8
Badminton	F	3	1225.2 ± 775.8	3464.0 ± 894.1	35.3 ± 17.1
Marathon	F	1	1086.3 ± 622.6	3334.0 ± 1004.5	30.4 ± 12.1
Wushu	F	1	933.2 ± 83.9	3202.9 ± 208.1	29.1 ± 0.7
Gymnastics	F	2	769.2 ± 59.6	2820.9 ± 228.7	27.4 ± 2.5
Windsurfing	M	4	1022.9 ± 344.1	5689.9 ± 1699.8	18.6 ± 5.3
Soccer	M	4	1551.2 ± 490.0	4507.9 ± 843.7	35.5 ± 11.7
Squash	M	2	841.5 ± 390.3	4140.5 ± 354.6	19.9 ± 8.4
High Jump	M	1	788.5	4006.1	19.7

* : X ± SD

Table 4
Energy Expenditure of athletes .*

Athletes	Energy Expenditure		
	Exercise Period (KCAL)	Whole Day (KCAL)	Percentage (%)
Male athletes	1232.9 ± 508.1	4934.9 ± 1377.2	26.4 ± 12.2
Female athletes	1106.2 ± 658.3	3309.4 ± 821.6	32.8 ± 14.1

* : X ± SD

Table 5

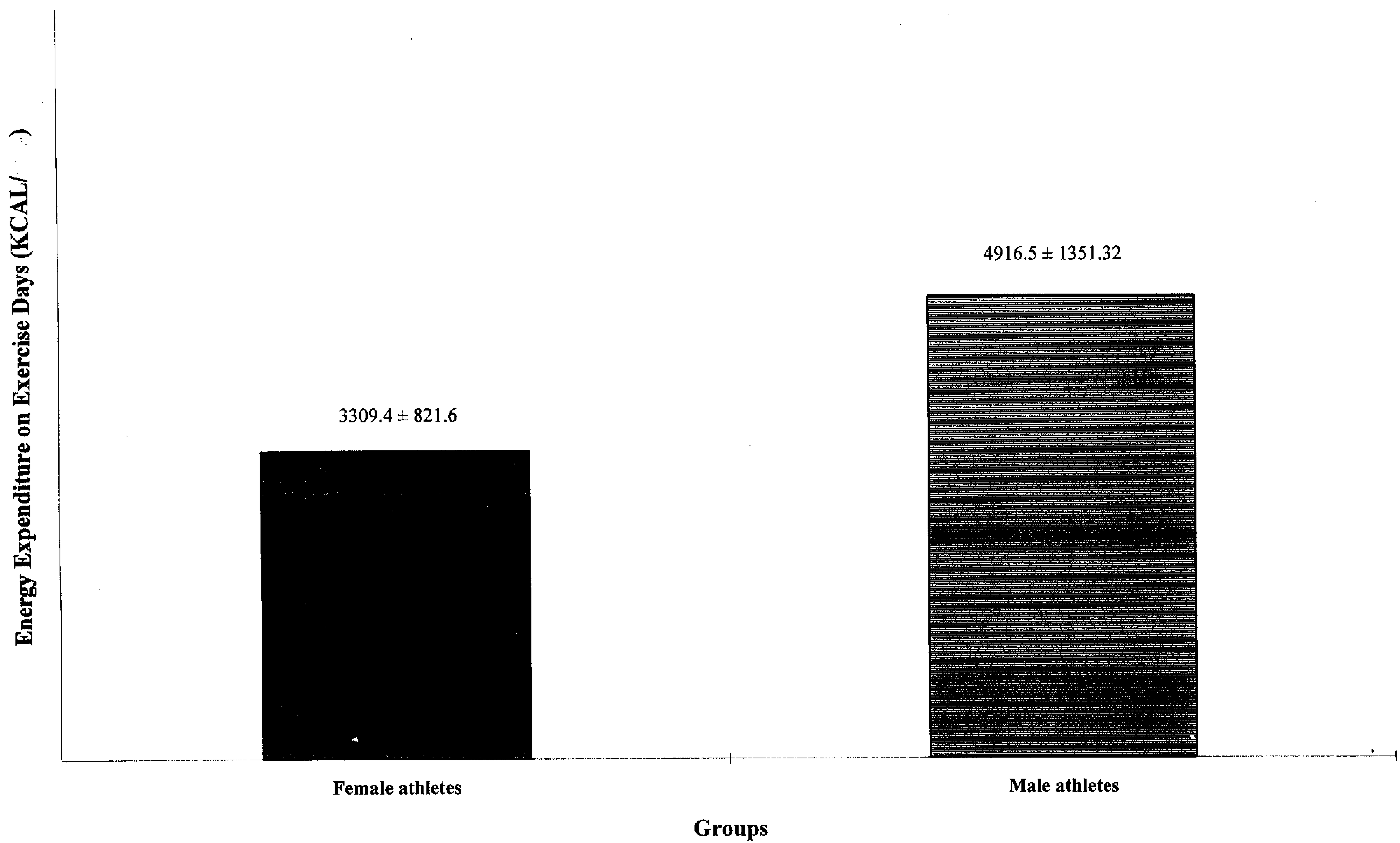

Energy Expenditure on Exercise Days (KCAL/)
3309.4 ± 821.6
4916.5 ± 1351.32
Female athletes
Male athletes
Groups

Table 6

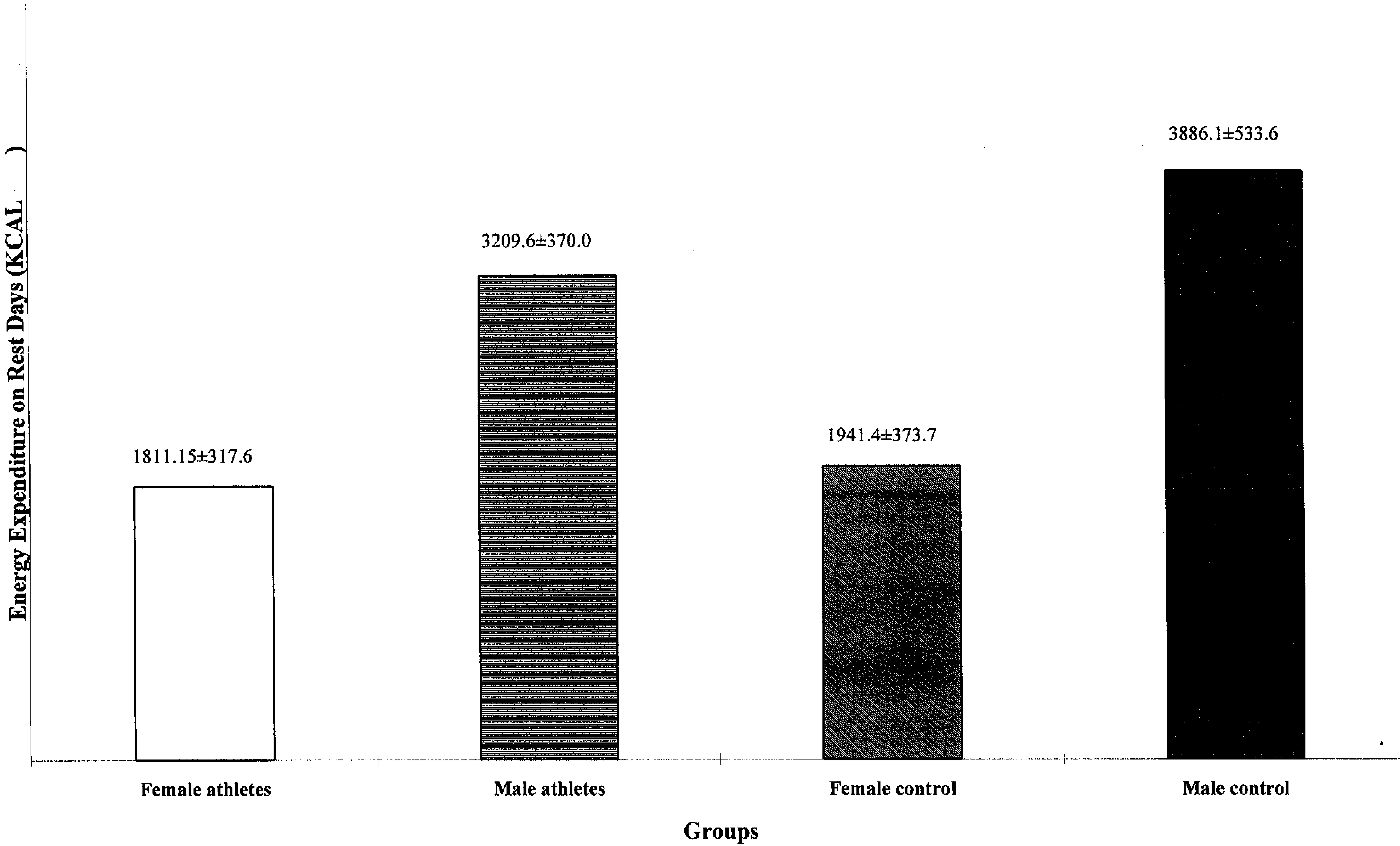

Energy Expenditure on Rest Days (KCAL)
1811.15±317.6
3209.6±370.0
1941.4±373.7
3886.1±533.6
Female athletes
Male athletes
Female control
Male control
Groups

Table 7
Mean daily intake of micronutrients(±SD) of athletes

Nutrient	Mean(±SD)	Density per 1000 kcal	mean %RDA*	Range %RDA	No. of athletes <70%RDA
calcium(mg)	1247 ± 698	320	118 ± 0.7	39 - 270	4
iron(mg)	29.7 ± 9.8	7.6	233 ± 0.8	138 - 346	0
zinc(mg)	13.6 ± 6.3	3.5	99 ± 0.5	42 - 237	6
thiamin(mg)	4.0 ± 3.2	1.0	310 ± 2.9	97 - 483	0
niacin(mg)	36.4 ± 12.7	9.3	207 ± 0.7	111-387	0
riboflavin(ma)	2.9 ± 1.8	0.7	190 ± 1.3	69 - 647	1
vitamin A(RE)	1597 ± 1059	410	180 ± 1.3	60 - 503	2
vitamin C(mg)	286 ± 181	73.4	477 ± 3.0	942- 135	0

*Recommended Daily Intake

Table 8
Mean daily intake of macronutrients (±SD) of athletes

	Mean (±SD)		mean nutrient intake per kg body weight		% of total calories	
	Male	Female	Male	Female	Male	Female
energy (kcal)	4450±1172	3135±968	67.8	57.3		
protein (g)	178±56	148±55	2.7	2.7	16	19
fat (g)	155±50	84±29	2.4	1.5	31	24
carbohydrate(g)	597±195	450±190	9.1	8.2	53	57

Table 9
Mean daily intake of macronutrients (±SD) of normal subjects

	Mean (±SD)		mean nutrient intake per kg body weight		% of total calories	
	Male	Female	Male	Female	Male	Female
energy (kcal)	3171±612	2077±111	51.1	44.1		
protein (g)	112±30	83±15	1.8	1.8	14	15
tat (g)	123±17	89±16	2.0	2.6	35	38
carbohydrate(g)	384±86	245±50	6.2	8.2	48	47

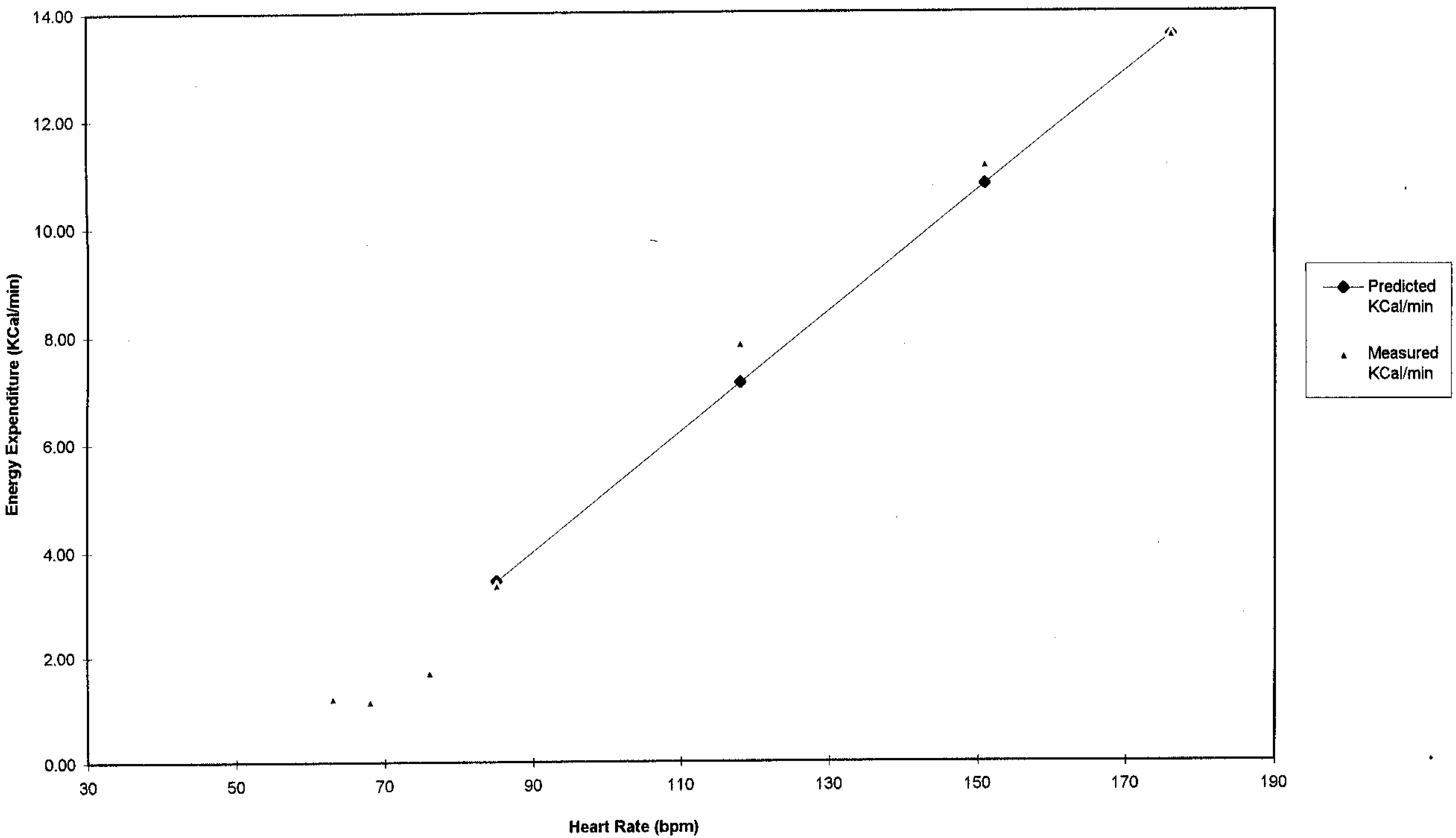
APPENDIX I

Schofield equation for Resting Metabolic Rate(BMR) :

		BMR (kcal/day)	Standard error of estimate
Males	10-17 y	17.7W + 657	105
	18-29	15.1W + 692	156
	30-59 Y	11.5W + 873	167
Females			
	10-17 y	13.4 W + 692	112
	18-29 y	14.8W + 487	120
	30-59 y	8.3W + 846	112

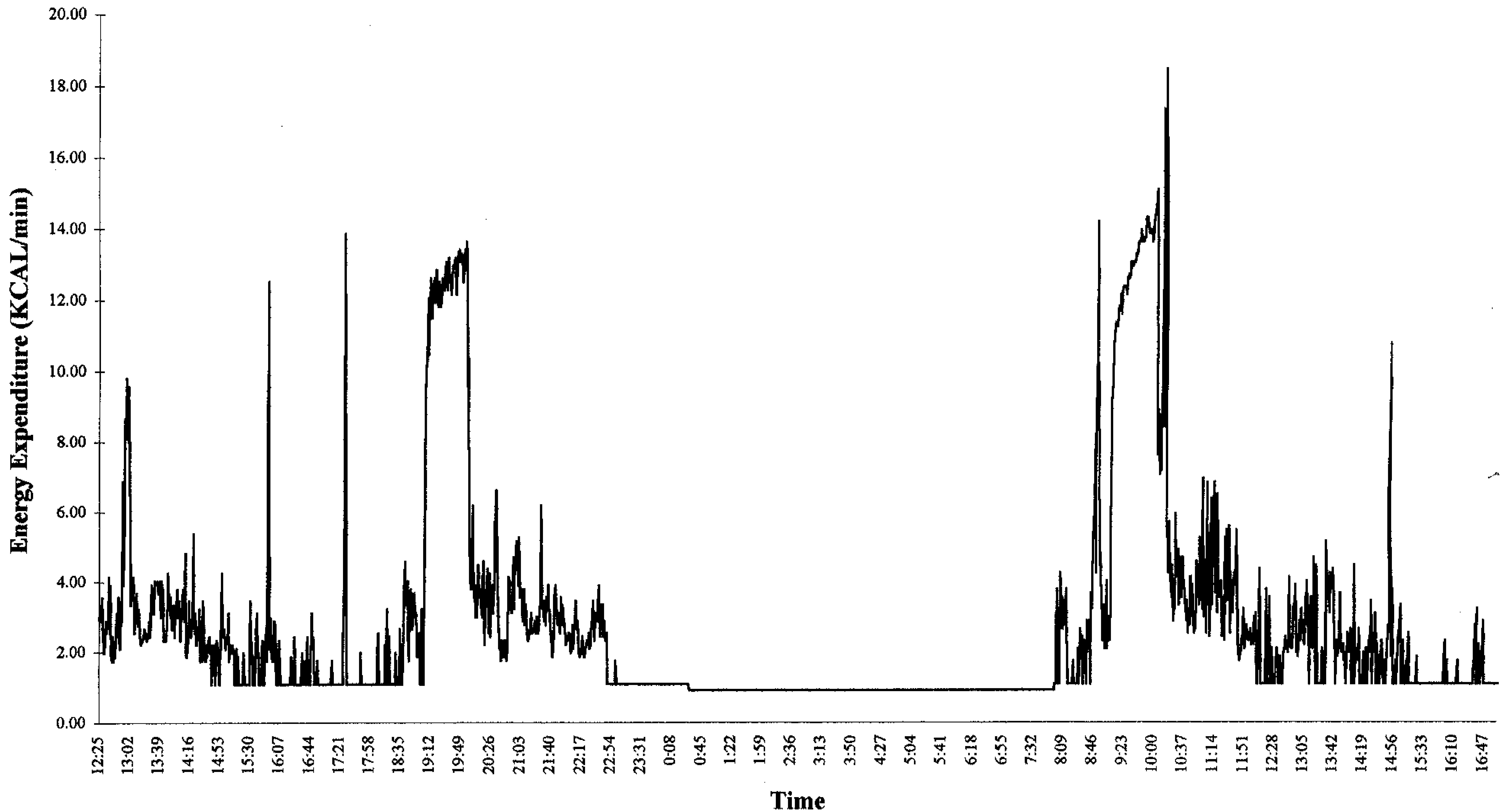
W = body weight (kg)

Appendix II



14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Energy Expenditure (KCal/min)
30
50
70
90
110
130
150
170
190
Heart Rate (bpm)
Predicted KCal/min
Measured KCal/min

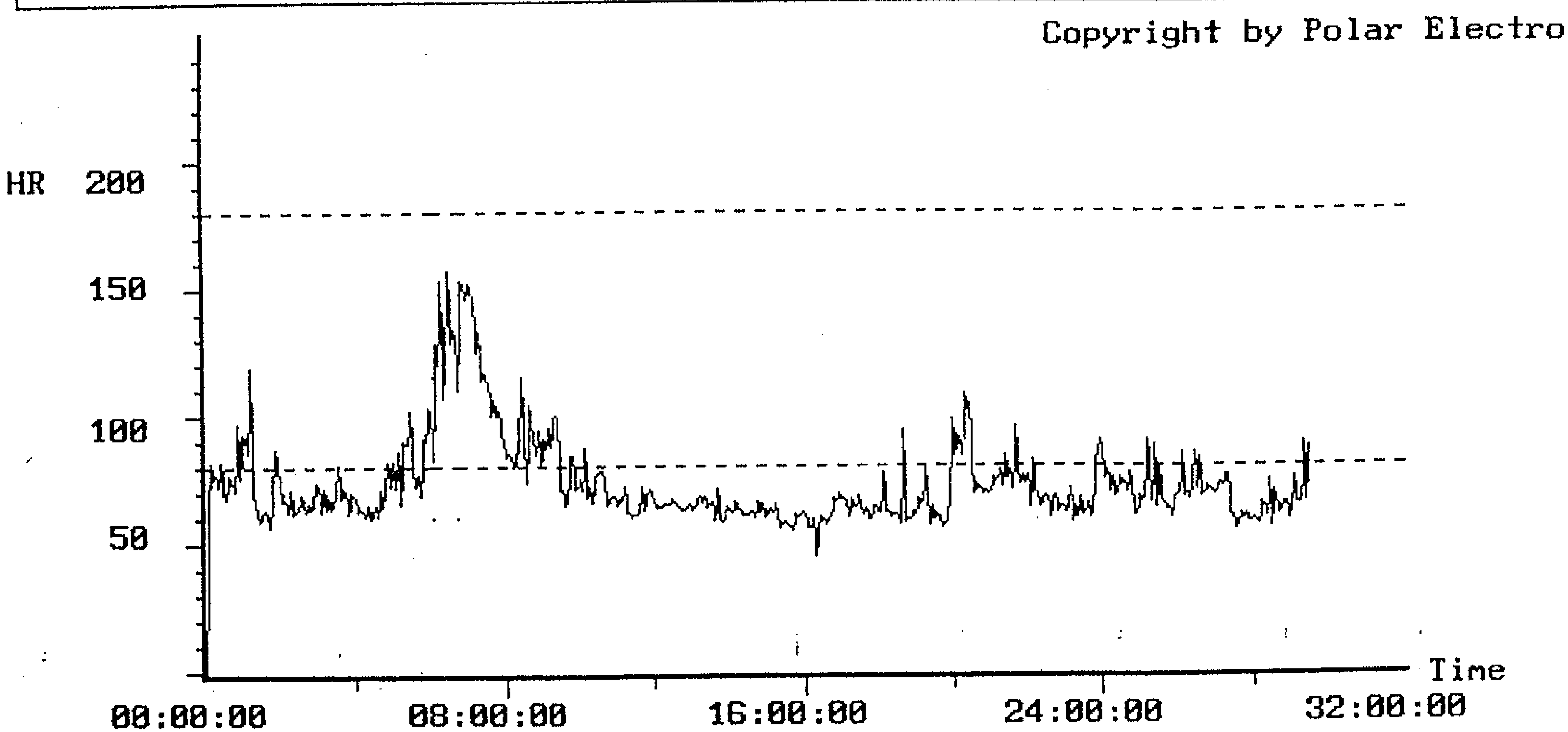
Appendix III (a)



								K	Ma							
0.91	78	1313	0.91	87	4183	2.90	92	4598	3.19	77	1313	0.91	68	1313	0.91	76
0.91	85	4016	2.79	77	1313	0.91	91	4515	3.14	76	1313	0.91	74	1313	0.91	75
0.91	85	4016	2.79	80	1313	0.91	92	4598	3.19	81	1313	0.91	71	1313	0.91	73
0.91	82	1313	0.91	81	1313	0.91	95	4848	3.37	73	1313	0.91	73	1313	0.91	76
0.91	82	1313	0.91	92	4598	3.19	99	5180	3.60	74	1313	0.91	76	1313	0.91	77
0.91	80	1313	0.91	93	4682	3.25	79	1313	0.91	78	1313	0.91	75	1313	0.91	75
0.91	76	1313	0.91	85	4016	2.79	78	1313	0.91	84	1313	0.91	78	1313	0.91	78
0.91	81	1313	0.91	84	1313	0.91	80	1313	0.91	89	4349	3.02	78	1313	0.91	74
0.91	78	1313	0.91	92	4598	3.19	82	1313	0.91	85	4016	2.79	79	1313	0.91	78
0.91	81	1313	0.91	84	1313	0.91	85	4016	2.79	80	1313	0.91	80	1313	0.91	102
0.91	81	1313	0.91	83	1313	0.91	112	6261	4.35	81	1313	0.91	77	1313	0.91	104
2.85	80	1313	0.91	85	4016	2.79	116	6594	4.58	88	4266	2.96	75	1313	0.91	101
2.90	78	1313	0.91	88	4266	2.96	87	4183	2.90	75	1313	0.91	87	4183	2.90	107
0.91	79	1313	0.91	103	5513	3.83	85	4016	2.79	94	4765	3.31	85	4016	2.79	121
0.91	83	1313	0.91	100	5264	3.66	88	4266	2.96	91	4515	3.14	97	5014	3.48	86
0.91	84	1313	0.91	95	4848	3.37	93	4682	3.25	85	4016	2.79	107	5846	4.06	92
0.91	79	1313	0.91	83	1313	0.91	91	4515	3.14	88	4266	2.96	100	5264	3.66	94
0.91	83	1313	0.91	94	4765	3.31	97	5014	3.48	76	1313	0.91	75	1313	0.91	94
0.91	82	1313	0.91	102	5430	3.77	100	5264	3.66	90	4432	3.08	72	1313	0.91	88
0.91	82	1313	0.91	99	5180	3.60	92	4598	3.19	95	4848	3.37	74	1313	0.91	82
0.91	77	1313	0.91	99	5180	3.60	93	4682	3.25	89	4349	3.02	71	1313	0.91	74
0.91	78	1313	0.91	98	5097	3.54	107	5846	4.06	95	4848	3.37	74	1313	0.91	100
0.91	77	1313	0.91	87	4183	2.90	89	4349	3.02	80	1313	0.91	72	1313	0.91	96
4.17	78	1313	0.91	77	1313	0.91	99	5180	3.60	84	1313	0.91	73	1313	0.91	77
3.48	79	1313	0.91	75	1313	0.91	83	1313	0.91	71	1313	0.91	71	1313	0.91	70
0.91	76	1313	0.91	75	1313	0.91	87	4183	2.90	89	4349	3.02	67	1313	0.91	103
0.91	77	1313	0.91	77	1313	0.91	86	4100	2.85	92	4598	3.19	72	1313	0.91	96
0.91	71	1313	0.91	84	1313	0.91	90	4432	3.08	88	4266	2.96	73	1313	0.91	74
0.91	75	1313	0.91	78	1313	0.91	90	4432	3.08	96	4931	3.42	73	1313	0.91	82
0.91	76	1313	0.91	75	1313	0.91	93	4682	3.25	71	1313	0.91	102	5430	3.77	77
0.91	74	1313	0.91	85	4016	2.79	82	1313	0.91	72	1313	0.91	93	4682	3.25	85
0.91	93	4682	3.25	74	1313	0.91	83	1313	0.91	80	1313	0.91	98	5097	3.54	87
0.91	86	4100	2.85	74	1313	0.91	86	4100	2.85	77	1313	0.91	85	4016	2.79	81
0.91	102	5430	3.77	75	1313	0.91	82	1313	0.91	73	1313	0.91	94	4765	3.31	81
0.91	106	5762	4.00	75	1313	0.91	85	4016	2.79	76	1313	0.91	94	4765	3.31	84
0.91	88	4266	2.96	77	1313	0.91	88	4266	2.96	76	1313	0.91	82	1313	0.91	85
0.91	81	1313	0.91	79	1313	0.91	88	4266	2.96	79	1313	0.91	98	5097	3.54	78
0.91	89	4349	3.02	77	1313	0.91	94	4765	3.31	81	1313	0.91	109	6012	4.17	77
0.91	91	4515	3.14	72	1313	0.91	89	4349	3.02	91	4515	3.14	96	4931	3.42	88
0.91	85	4016	2.79	79	1313	0.91	87	4183	2.90	80	1313	0.91	97	5014	3.48	87
0.91	90	4432	3.08	81	1313	0.91	86	4100	2.85	81	1313	0.91	93	4682	3.25	91
0.91	76	1313	0.91	83	1313	0.91	85	4016	2.79	73	1313	0.91	98	5097	3.54	91
0.91	76	1313	0.91	88	4266	2.96	85	4016	2.79	75	1313	0.91	94	4765	3.31	86
0.91	76	1313	0.91	89	4349	3.02	93	4682	3.25	74	1313	0.91	91	4515	3.14	85
0.91	79	1313	0.91	93	4682	3.25	87	4183	2.90	89	4349	3.02	91	4515	3.14	99
0.91	84	1313	0.91	91	4515	3.14	89	4349	3.02	77	1313	0.91	87	4183	2.90	-94
0.91	78	1313	0.91	88	4266	2.96	89	4349	3.02	82	1313	0.91	90	4432	3.08	84
0.91	79	1313	0.91	90	4432	3.08	86	4100	2.85	78	1313	0.91	102	5430	3.77	77
0.91	78	1313	0.91	83	1313	0.91	86	4100	2.85	75	1313	0.91	94	4765	3.31	79
0.91	74	1313	0.91	84	1313	0.91	96	4931	3.42	77	1313	0.91	105	5679	3.94	88
0.91	75	1313	0.91	91	4515	3.14	85	4016	2.79	82	1313	0.91	92	4598	3.19	83
0.91	81	1313	0.91	90	4432	3.08	84	1313	0.91	78	1313	0.91	94	4765	3.31	86
0.91	105	5679	3.94	77	1313	0.91	81	1313	0.91	77	1313	0.91	91	4515	3.14	87
0.91	102	5430	3.77	78	1313	0.91	78	1313	0.91	77	1313	0.91	91	4515	3.14	71
2.79	92	4598	3.19	83	1313	0.91	79	1313	0.91	76	1313	0.91	80	1313	0.91	74
0.91	93	4682	3.25	86	4100	2.85	76	1313	0.91	95	4848	3.37	75	1313	0.91	77
0.91	91	4515	3.14	79	1313	0.91	81	1313	0.91	85	4016	2.79	73	1313	0.91	73
0.91	99	5180	3.60	92	4598	3.19	84	1313	0.91	75	1313	0.91	71	1313	0.91	76
0.91	94	4765	3.31	85	4016	2.79	80	1313	0.91	75	1313	0.91	74	1313	0.91	70
0.91	79	1313	0.91	83	1313	0.91	76	1313	0.91	70	1313	0.91	69	1313	0.91	69
2:30pm			1:30pm			2:30pm			3:33pm			4:33pm			5:33pm	
66.36			96.94			to			151.49			96.10			125.90	
						2:41pm										
						2:45pm										
						118.08										

Appendix IV (b)

HEART RATE CURVE



Heart rate Ng Siu Ching Mar8 12:25pm to Mar9 6:00pm
Time:00:00:00 Heart Rate:0 bpm B:\NSC8MARB.RAW

Appendix IV (a)

Activity Record - N · S C Mar8, 94

時間 下午	活動 (睡,坐,行,跑)
5:00-5:10	坐.
5:10-5:20	行.
5:20-5:30	
5:30-5:40	坐.
5:40-5:50	行.
5:50-6:00	
6:00-6:10	Warm up.
6:10-6:20	
6:20-6:30	
6:30-6:40	
6:40-6:50	
6:50-7:00	Training.
7:00-7:10	
7:10-7:20	
7:20-7:30	
7:30-7:40	
7:40-7:50	
7:50-8:00	企.
8:00-8:10	
8:10-8:20	坐.
8:20-8:30	
8:30-8:40	
8:40-8:50	
8:50-9:00	行

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