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# Energy expenditure studies to predict requirements of selected national athletes

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## ABSTRACT

A study to predict energy requirements of national athletes, 84 males and 24 females in 9 and 4 different types of sports respectively, were conducted during centralised training. Parameters assessed were anthropometry, 3-day activity pattern and energy cost (kcal/min) of common activities to derive total daily energy expenditure (TDEE). Based on body mass index (BMI), 68 males or 81% and 19 females or 79% of the athletes were classified as normal. The mean body fat content for males and females were 13.8 ± 4.5% and 24.7 ± 5.3%, respectively. The mean daily activity pattern of males and females athletes were similar for light activities (16½ hr or 68% of day), for moderate activities (3½ hr or 15% of day in male, 4 hr or 17% in females) while moderate to heavy activities related to training were 4 hr (17%) and 3½ hr (15%) in males and females, respectively. Energy cost of some common activities ranges from 1.00-3.00 kcal/min in males and 0.84-2.04 kcal/min in females, while values for jogging were 6.60 kcal/min and 5.62 kcal/min in males and females, respectively. The mean TDEE in male ranges from 2938 kcal (12.3 MJ) in boxers (57 kg) to 4861 kcal (20.3 MJ) in weightlifters (110 kg) while the mean TDEE in female ranges from 2099 kcal (8.8 MJ) in athletics (51 kg) to 3098 kcal (13.0 MJ) in basketball (61.4 kg). The calculated physical activity level (PAL) values using measured BMR for males and females athletes ranges from 1.99-2.58 and 1.77-2.34, respectively. In conclusion, the estimated energy requirement for the various sports event studied ranges from 44-55 kcal/kg/day in males and 38-50 kcal/kg/day in female athletes.

## INTRODUCTION

Energy intake studies in relation to physical performance during training and competition have been the subject of research interest during the past decades (Grandjean, 1989; Chen *et al.,* 1989; van Erp-Baart *et al.,* 1989; Papadokonstantaki *et al.,* 1993). The energy requirement of an individual as defined in the FAO/WHO/UNU (1985) report states that "the energy requirement of an individual is the level of energy intake from food that will balance energy expenditure when the individual has a body size and composition, and level of physical activity, consistent with long-term good health; and that will allow for the maintenance of economically necessary and socially desirable physical activity". However, in a highly competitive world of sports, the concern about energy must go beyond health and socially desirable activity. It is now clear that the demand for energy varies accordingly to the different training programmes and also differs from one sporting event to another.

The FAO/WHO/UNU (1985) report on energy and protein requirements proposed the use of energy expenditure rather than energy intake as the basis for estimating energy needs in man. Unlike energy intake, reports on energy expenditure studies in competitive sports are limited (Westerterp *et al.,* 1986; Saris *et al.,* 1989)

In Malaysia, energy expenditure studies were mainly conducted in nonathletic populations namely, obese students (Ismail & Chi, 1987); university students (Ismail & Zawiah, 1988); adult Malaysians (Ismail *et al.,* 1994); soldiers (Ismail, Isa & Janudin, 1996) with the exception of one study, a sepak takraw team (Ismail, Wan Nudri & Zawiah, 1995) conducted initially, from a larger pool of national athletes presented in this study. The aim of this study was to assess the physical activity level and the energy requirements and to provide the much needed guidelines on energy intakes for the national athletes during centralised training.

## MATERIALS AND METHODS

The athletes and types of sports selected were based on medals prospect as determined by the National Sports Council of Malaysia (NSC). A total of 84 male athletes from 9 types of sports and 24 female athletes from 4 types of sports participated in the study. All measurements were conducted during centralised training.

### *Anthropometry*

The height and body weight of subjects (barefoot and in light clothing) were measured to the nearest 0.5cm and 0.1kg respectively, using the Seca weighing balance with attachment for measuring height. Skinfold thickness measurements were taken using the Harpenden Calipers (British Indicators, UK) at 4 sites as recommended by Durnin and Rahaman (1967). Fat content as a percentage of body weight, was calculated from the sum of 4 measurements of skinfold thickness (Durnin & Womersley, 1974). The body mass index ($kg/m^2$) and lean body mass (kg) were also calculated for each subject.

### *Activity Pattern*

Subjects were instructed to accurately fill the diary card in order to provide, as detailed as possible, information on their daily activity patterns (Durnin & Passmore, 1967). Day time activities were constantly monitored by a trained nutritionist, and subjects were individually questioned in cases where irregularities in recording were encountered. Their activities were classified broadly into three categories: light, moderate and heavy. The daily activity pattern during training were reported as a mean of 3-days' activity records.

### *Energy Expenditure*

Daily energy expenditure was assessed by using the time-motion study. The energy cost of some common activities was measured by indirect calorimetry using the Douglas bag technique. The energy cost (kcal/min) was calculated using the Weir formula (1949). The detailed protocol is similar to that reported in earlier studies (Ismail & Chi, 1987; Ismail & Zawiah, 1988). The

limited time available during the centralised training does not permit us to measure all subjects hence, sub-sample were studied. The mean values obtained were used to calculate the energy expenditure for the group. The energy cost of activities that was not measured was derived from the table suggested by Durnin and Passmore (1967). The total daily energy expenditure (TDEE) was calculated by summing up the energy cost for each activity (adjusted for body weight) multiplied by the mean duration of that activity for each subject.

*Physical Activity Level*

To calculate the physical activity level (PAL) of athletes, the total daily energy expenditure (TDEE) is divided by the basal metabolic rate (BMR) (James & Schofield, 1990). Two PAL values were derived using the following BMR equations:

Male (18-29+ years)
BMR (MJ/day) predicted
- 2.84 + 0.064W
  (FAO/WHO/UNU, 1985)
BMR (MJ/day) measured
- 2.717 + 0.056W
  (Ismail *et al,* 1994)

Female (18-29+ years)
BMR (MJ/day) predicted
- 2.08 + 0.0615W
  (FAO/WHO/UNU, 1985)
BMR (MJ/day) measured
- 2.035 + 0.057W
  (Ismail *et al,* 1994)

W is the weight in kg

## RESULTS

The physical characteristic of male athletes is shown in Table 1. With the exception of discus, basketball and weightlifters group II (84-110kg), the mean body weight is closely matched in a number of different sports (61-67 kg). Percentage body fat ranges from 8.8% to 18.0%. The inherent limitation of measuring skinfold is apparent in weightlifters group II which recorded 27.2% body fat.

The daily activity pattern of male athletes during centralised training is shown in Table 2. Overall, male athletes spends about 16½ hours (68% of day) doing light activities such as sleeping, sitting activities and standing quietly; 3½ hours (15% of day) doing moderate activities such as walking, up/down stairs, praying and personal activities; and 4 hours (17%) doing moderate to heavy activities related to training.

**Table 1.** Physical characteristics of male athletes (mean ± SD)

| Type of sport | n | Age (yr) | Weight (kg) | Height (m) | Body fat (%) | LBM (kg) | BMI (kg/m²) |
|---|---|---|---|---|---|---|---|
| 1.Athletics | 6 | 23.5±3.7 | 63.3±4.4 | 1.72±0.06 | 9.3±1.6 | 57.3±3.7 | 21.0±0.3 |
| Discus | 1 | 25 | 85.5 | 1.73 | 17.1 | 70.9 | 28.6 |
| 2. Badminton | 7 | 16.4±0.9 | 61.3±4.9 | 1.67±0.05 | 14.6±2.9 | 52.2±5.8 | 22.0±1.8 |
| 3. Basketball | 11 | 24.4±3.3 | 84.3±5.2 | 1.88±0.05 | 14.1±2.3 | 72.4±3.6 | 23.9±1.4 |
| 4. Boxing | 7 | 27.7±3.2 | 56.9±6.2 | 1.65±0.05 | 14.3±2.0 | 48.7±4.5 | 20.9±1.8 |
| 5. Hockey | 15 | 25.1±2.8 | 67.4±6.7 | 1.73±0.07 | 11.4±2.5 | 59.7±5.9 | 22.5±1.5 |
| 6. Sepaktakraw | 17 | 23.9±2.4 | 64.7±4.9 | 1.73±005 | 15.2±2.8 | 54.8±3.4 | 21.6±1.6 |
| 7. Silat | 6 | 25.5± 1.4 | 67.3± 17.0 | 1.71±0.09 | 12.1±5.3 | 58.2±10.2 | 22.6±3.8 |
| 8. Swimming | 6 | 18.0±1.6 | 65.1±5.8 | 1.74±0.06 | 8.8±1.8 | 59.4±5.5 | 21.4±1.3 |
| 9. Weightlifting | | | | | | | |
| Group I | 5 | 27.8±2.1 | 63.9±8.7 | 1.60±0.05 | 18.0±4.1 | 52.1±5.3 | 25.0±2.3 |
| Group II | 3 | 27.0±5.7 | 110.0±7.4 | 1.73±0.00 | 27.2±1.3 | 80.0±4.0 | 36.9±1.5 |

**Table 2.** Daily activity pattern (mm/day) of male athletes during centralised training (mean ± SD)

| Type of sport | n | Light | | Moderate | | Active | |
|---|---|---|---|---|---|---|---|
| | | min | % | min | % | min | % |
| 1. Athletics | 6 | 1041± 93 | 72 | 192±34 | 13 | 207±42 | 15 |
| Discus | 1 | 1008 | 70 | 227 | 16 | 205 | 14 |
| 2. Badminton | 7 | 991±106 | 69 | 183±36 | 13 | 266±23 | 18 |
| 3. Basketball | 11 | 981±111 | 68 | 216±35 | 15 | 243±0 | 17 |
| 4. Boxing | 7 | 1018±84 | 71 | 171±28 | 12 | 251±5 | 17 |
| 5. Hockey | 15 | 990±1003 | 69 | 209±53 | 14 | 241±0 | 17 |
| 6. Sepaktakraw | 17 | 938±135 | 65 | 222±50 | 15 | 280±77 | 20 |
| 7. Silat | 6 | 952±87 | 66 | 250±47 | 17 | 238±10 | 17 |
| 8. Swimming | 6 | 998±56 | 69 | 219±44 | 15 | 223±6 | 16 |
| 9. Weightlifting | | | | | | | |
| Group I | 5 | 1011±12 | 70 | 237±50 | 17 | 192±17 | 13 |
| Group II | 3 | 1051±82 | 73 | 212±40 | 15 | 177±12 | 12 |

The energy cost (kcal/min) for the more common daily activities in males is shown in Table 3. The mean values for lying, sitting quietly, standing quietly, walking, up/down stairs, jogging and praying were 1.00, 1.24, 1.44, 3.00, 4.29, 6.60 and 1.79 kcal/min, respectively. A considerable variation in energy cost for similar activity was recorded which was mainly due to differences in body weight of the athletes.

The total daily energy expenditure in male athletes ranges from 2938 kcal (boxing) to 4861 kcal (weightlifting group II) while estimated energy requirement ranges from 44 to 55 kcal/kg body weight/day (Table 4). Physical activity level (PAL) of male athletes calculated using local BMR data ranges from 1.99 to 2.58 while those derived using predicted BMR (FAO/WHO/UNU, 1985) ranges from 1.72 to 2.38 (Table 5).

**Table 3.** Energy cost (kcal/min) of common daily activities of male athletes

| Activities | n | Mean | S.D. | Range |
|---|---|---|---|---|
| Lying | 16 | 1.00 | 0.10 | 0.88 - 1.17 |
| Sitting | 16 | 1.24 | 0.18 | 0.94 - 1.64 |
| Standing | 16 | 1.44 | 0.20 | 1.06 - 1.95 |
| Walking | 16 | 3.00 | 0.45 | 2.17 - 3.70 |
| Up/Down stairs | 14 | 4.29 | 0.48 | 3.54 - 5.25 |
| Jogging | 15 | 6.60 | 1.28 | 3.38 - 8.66 |
| Praying | 5 | 1.79 | 0.07 | 1.71 - 1.88 |

**Table 4.** Total daily energy expenditure of male athletes during centralised training (mean ± SD)

| Type of sport | n | Total daily energy expenditure | |
|---|---|---|---|
| | | kcal/day | kcal/kg/day |
| 1. Athletics | 6 | 2989 ± 286 | 47 |
| Discus | 1 | 4104 | 48 |
| 2. Badminton | 7 | 2963 ± 255 | 48 |
| 3. Basketball | 11 | 4584 ± 277 | 55 |
| 4. Boxing | 7 | 2938 ± 340 | 53 |
| 5. Hockey | 17 | 3534± 447 | 51 |
| 6. Sepaktakraw | 17 | 3191 ± 447 | 49 |
| 7. Silat | 6 | 3772 ± 898 | 55 |
| 8. Swimming | 6 | 3285 ± 271 | 52 |
| 9. Weightlifting | | | |
| Group I | 5 | 2991 ± 511 | 46 |
| Group II | 3 | 4861 ± 419 | 44 |

**Table 5.** Physical activity level (PAL) of male athletes

| Type of Sport | Energy Expenditure kcal/day | BMR (kcal/day) | | PAL | |
|---|---|---|---|---|---|
| | | Measured[1] | Predicted[2] | 1 | 2 |
| 1. Athletics | 2989 | 1497 | 1647 | 2.00 | 1.81 |
| Discus | 4101 | 1794 | 1987 | 2.29 | 2.07 |
| 2. Badminton | 2963 | NA | 1724 | NA | 1.72 |
| 3. Basketball | 4584 | 1778 | 1969 | 2.58 | 2.38 |
| 4. Boxing | 2938 | 1411 | 1550 | 2.08 | 1.89 |
| 5. Hockey | 3534 | 1551 | 1710 | 2.28 | 2.06 |
| 6. Sepaktakraw | 3191 | 1515 | 1669 | 2.11 | 1.91 |
| 7. Silat | 3772 | 1550 | 1709 | 2.43 | 2.21 |
| 8. Swimming | 3285 | NA | 1790 | NA | 1.83 |
| 9. Weightlifting | | | | | |
| Group I | 2991 | 1505 | 1657 | 1.99 | 1.80 |
| Group II | 4861 | 2123 | 2364 | 2.29 | 2.06 |

BMR[1] - Ismail et al (1994), BMR[2] - FAO/WHO/UNU (1985), NA - Not available

**Table 6.** Physical characteristics of female athletes (mean ± SD)

| Type of Sport | n | Age (yr) | Weight (kg) | Height (m) | Body fat (%) | LBM (kg) | BMI ($kg/m^2$) |
|---|---|---|---|---|---|---|---|
| 1. Athletics | 3 | 22.0± 0.8 | 51.3±1.2 | 1.66±0.03 | 17.4±1.4 | 42.4± 1.7 | 18.6±1.0 |
| Shot-putt | 1 | 27 | 71.8 | 1.69 | 32.3 | 48.6 | 25.1 |
| 2. Basketball | 13 | 21.6±1.9 | 61.4±5.4 | 1.70±0.07 | 25.6±4.7 | 45.6± 3.6 | 21.2±1.4 |
| 3. Silat | 2 | 25.5±4.5 | 51.0±11 | 1.54±0.07 | 24.5±8.9 | 37.6±3.8 | 21.5±3.0 |
| 4. Swimming | 5 | 16.2±2.1 | 53.1±3.1 | 1.61±0.04 | 25.3±1.3 | 39.7±1.7 | 20.6±1.5 |

The physical characteristics of female athletes is shown in Table 6. Mean body weight ranges from 51kg to 72kg, percentage body fat, from 17.4% to 32.3%, the latter (shot-putt) may be overestimated due to muscle mass.

The daily activity pattern of female athletes (Table 7) is quite similar to that of male athletes with the exception that they spend on an average 30 minutes less in moderate to heavy activities related to training. Light activities constitute 16½ hours, moderate 4 hours and active mainly training 3½ hours of the day.

The energy cost of some common activities is shown in Table 8. The mean values were, lying (0.84 kcal/min) sitting quietly (0.97 kcal/min), standing quietly (1.13 kcal/min), walking (2.04 kcal/min), up/down stairs (3.93 kcal/min), jogging (5.62 kcal/min) and praying (1.65 kcal/min). Just like the males, the metabolic cost in female athletes vary according to the body weight.

**Table 7.** Daily activity pattern (min/day) of female athletes during centralised training (mean ± SD)

| Type of sport | n | Light | | Moderate | | Active | |
|---|---|---|---|---|---|---|---|
| | | min | % | min | % | min | % |
| 1. Athletics | 3 | 1070± 73 | 74 | 212±32 | 15 | 158±39 | 11 |
| Shot-putt | 1 | 1091 | 76 | 169 | 12 | 180 | 12 |
| 2. Basketball | 13 | 985±64 | 68 | 224±41 | 16 | 231±0 | 16 |
| 3. Silat | 2 | 925±80 | 64 | 274±8 | 19 | 241±3 | 17 |
| 4. Swimming | 5 | 968± 116 | 67 | 248±33 | 17 | 224±5 | 16 |

**Table 8.** Energy cost (kcal/min) of common daily activities of female athletes

| Activities | n | Mean | S.D. | Range |
|---|---|---|---|---|
| Lying | 3 | 0.84 | 0.02 | 0.83 - 0.87 |
| Sitting | 3 | 0.97 | 0.05 | 0.90 - 1.02 |
| Standing | 3 | 1.13 | 0.05 | 0.92 - 1.23 |
| Walking | 3 | 2.04 | 0.26 | 1.42 - 2.28 |
| Up/Down stair | 3 | 3.93 | 0.66 | 3.10 - 4.60 |
| Jogging | 3 | 5.62 | 1.59 | 3.38 - 6.88 |
| Praying | 3 | 1.65 | 0.12 | 1.51-1.82 |

The total daily energy expenditure of female athletes ranges from 2295 kcal (mostly adolescent) to 3098 kcal in basketball players while estimated energy requirement ranges from 40 to 50 kcal/kg body weight/day (Table 9). Their physical activity level (PAL) were between 1.77 to 2.34 using local BMR data and between 1.65-2.21 when predicted BMR (FAO/WHO/UNU, 1985) were used (Table 10).

## DISCUSSION

The anthropometric data revealed that although the mean body weight is closely matched in a number of different sports, there exist a wide range of body weight within each type of sports. Detailed discussion on the physical characteristics of male and female national athletes has been reported earlier (Wan Nudri, Ismail & Zawiah, 1996). In a study on Thai Olympic amateur boxers (Kijboonchoo *et al,* 1991) reported that, with the exception of body fat (10.6 ± 1.4%) as compared to 14.3 ± 2.0% in Malaysian boxers, the mean body weight were quite similar, 57.8 ± 5.5kg as compared to 56.9 ± 6.2kg, respectively, while their mean height were similar at 1.65m. Depending on the type of sports, elite athletes are under immense pressure to achieve an ideal body physique. Coaches and athletes are in constant dilemma as to what constitute desirable body weight and body fat to enhance performance. There are probably many opinion on the matter but what is certain in a highly competitive world of sports today is that, they will attempt to do whatever they believe to win "gold" through dietary manipulation to achieve the desired body composition.

**Table 9.** Total daily energy expenditure of female athletes during centralised training (mean ± SD)

| Type of sport | n | Total daily energy expenditure | |
|---|---|---|---|
| | | kcal/day | kcal/kg/day |
| 1. Athletics | 3 | 2099 ± 279 | 40 |
| Shot-putt | 1 | 2731 | 38 |
| 2. Basketball | 13 | 3098 ± 269 | 50 |
| 3. Silat | 2 | 2522 ± 531 | 49 |
| 4. Swimming | 5 | 2295 ± 134 | 43 |

**Table 10.** Physical activity level (PAL) of female athletes

| Type of Sport | Energy Expenditure kcal/day | BMR (kcal/day) | | PAL | |
|---|---|---|---|---|---|
| | | Measured[1] | Predicted[2] | 1 | 2 |
| 1. Athletics | 2099 | 1185 | 1251 | 1.77 | 1.68 |
| Shot-putt | 2731 | 1465 | 1553 | 1.86 | 1.76 |
| 2. Basketball | 3098 | 1323 | 1400 | 2.34 | 2.21 |
| 3. Silat | 2522 | 1181 | 1247 | 2.14 | 2.02 |
| 4. Swimming | 2295 | NA | 1394 | NA | 1.65 |

BMR[1] - Ismail et al (1994)
BMR[2] - FAO/WHO/UNU (1985)
NA - Not available (mostly adolescents)

The activity patterns for both male and female athletes for different sports reflect the centralised training programme they were undergoing hence, time spent on various activities related to training were fairly consistent. In comparison with normal adult population in Malaysia who spent 2-3% of the day, doing heavy activities (Ismail *et al*, 1994), the athletes on an average spent 15-17% of the day in activities related to training. The time spent for heavy activities (17% of day) were similar to that of soldiers residing in base camp (Ismail, Isa & Janudin, 1996). In estimating energy expenditure of any individual, it is known that larger errors are likely to arise from the failure to determine correctly the length of time spent in doing the prescribe activity rather than the assessment of the metabolic cost of that activity. It is therefore necessary to monitor closely athletes activity in order to avoid errornous estimate of total daily energy expenditure.

The metabolic cost (kcal/min) of common daily activities of athletes were consistently higher when compared to earlier studies in nonathlete Malaysian. Several studies has also been reported that energy cost at rest and work in the tropics are lower than those reported in temperate climate (Saha *et al*, 1985; Thongprasert & Chaivatsagool, 1985; Ismail & Zawiah, 1988). It is therefore important to use local data (if available) to avoid over-estimation of energy requirement.

Total daily energy expenditure is influenced by three major factors, namely, basal metabolic rate (BMR) or sometime referred as resting metabolic rate (RMR), thermogenesis and physical activity all of which are affected, directly or indirectly by age, sex, body size and climate (Pellett, 1990). Several studies have reported differences in resting metabolic rate between trained and untrained males subjects (Lennon *et al*, 1985; Poehlman *et al*, 1988).

Kijboonchoo *et al* (1991) reported a mean daily energy expenditure of 3410 ± 350kcal in Thai boxers, higher than that recorded for Malaysian boxers (2938 ± 340kcal). The difference observed, despite quite similar body weight may be explained by the use of mostly adopted values (Passmore & Durnin, 1955) for energy cost of activities and as suggested by the author may overestimate energy expenditure. Furthermore, while our study measures the athletes, the energy expenditure of Thai boxers were derived from values reported by Thongprasert *et al* (1985) who studied nonathlete population.

The FAO/WHO/UNU (1985) report has proposed that the average daily desirable activity allowance of adults be expressed as PAL (Physical activity level) value. Two important components to derive PAL value are, total daily energy expenditure (TDEE) and basal metabolic rate (BMR). Using the measured BMR values of adult Malaysians (Ismail *et al*, 1994) we were able to compare PAL using BMR predicted values suggested by FAO/WHO/UNU (1985). The measured BMR in males were 10-13% and in females 5-8% lower than the predicted BMR values derived from FAO/WHO/UNU (1985) equations, but were in close agreement with Henry & Rees (1991) equations, which are derived from populations living in the tropics. The difference in PAL values was expected as seen in Table 5 for male and Table 10 for female athletes. Comparison for badminton and swimming (both sexes) were not made because the athletes are adolescents and we do not have measured BMR for this age-group when the study was conducted.

## CONCLUSION

The study being first of its kind involving national athletes provide the much needed baseline data on energy requirements of this selected sports. We propose that the recommended daily energy intake for male athletes according to various types of sports range from 44-55 kcal/kg/day and female athletes between 38-50 kcal/ kg/day.

There is a need for more research to be conducted locally, since each athlete's energy requirement varies from others. While Malaysia strive hard to be an entity to be reckon in organising international sporting events at the "highest level", it is imperative that we work as hard to prepare our national athletes to match it.

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