Dietary intakes of age-group swimmers

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The purposes of this study were to collect information regarding the dietary habits of male and female age-group swimmers and report the energy consumptions of these athletes in relation to their daily training demands. Twenty competitive swimmers, who were training 6000 m per day 6 days a week, recorded all fluid and food consumed during a 4-day period. Dietary analysis revealed that 11 swimmers (55%) had calcium intakes below recommended dietary allowances (RDA), while 13 (65%) had iron intakes lower than RDA. Despite identical training loads and body mass, male swimmers had significantly greater ($P = 0.004$) daily mean (s.d.) energy consumption (3072(732) kcal, 12.9(3.1) MJ) than females (2130(544) kcal, 8.9(2.3) MJ) and were maintaining energy balance. Although the contribution of carbohydrate to total daily energy intake was the same for male (55%) and female swimmers (56%), the females ingested significantly less ($P = 0.011$) carbohydrate (292(87) g) than the males (404(88) g) and could be considered deficient in dietary carbohydrate with respect to their daily training demands.

Keywords: Dietary carbohydrate, exercise, fat, minerals, protein, swimming, vitamins

Exercise scientists and coaches commonly accept that success in swimming requires progressive increases in training stimulus. College swimmers typically train between 10000 and 14000 m per day with a large proportion of this workload being performed at high intensity¹. The recent development of age-group swimming programmes has resulted in the prescription of severe endurance training regimens for young children².

Competitive swimmers may expend up to 5000 kcal (21.0 MJ) during 4 h of training and have energy expenditures 1.5–3 times higher than active, untrained individuals^{3,4}. Furthermore, up to 40% of the swimmer's total daily energy expenditure may occur in just 2–4 h of intense training. Therefore, if only normal daily eating patterns are maintained, the swimmer's nutritional intake could be severely inadequate.

An athlete's carbohydrate stores are an important determinant of performance during prolonged (>60 min) intense exercise^{5–11}. Indeed, carbohydrate is the preferred fuel for muscle metabolism when the intensity of exercise is >65% of maximal oxygen uptake ($\dot{V}O_{2, \max}$)^{7,10}. Thus, endurance athletes must ensure a high carbohydrate intake to enhance muscle and liver glycogen stores between training sessions. In this respect Costill *et al.* reported a significant relationship ($r = 0.84$) between carbohydrate ingestion and the net amount of muscle glycogen synthesized after strenuous exercise⁶. Further, Costill and Miller have advocated a diet from which 70% of total calories are derived from carbohydrate for the endurance athlete involved in hard day to day training⁷.

The carbohydrate content of the endurance athlete's diet averages 46% of total energy intake⁴, which is between 14% and 24% lower than that recommended by sports nutritionists and exercise physiologists^{4,6,7,12,13}. Thus, both elite and non-elite athletes generally consume a diet which is significantly deficient in carbohydrate¹².

Despite the considerable number of publications concerned with sports nutrition, few formal studies of the dietary intake and eating behaviour of athletes have been published. Indeed, Brotherhood argues that sports medicine is making recommendations about the role of nutrition in the preparation of athletes without precise knowledge of their eating habits⁴. Of those studies which have examined the dietary patterns of athletic groups, many fail to report such fundamental data as body mass, body composition or training patterns of the athletes under investigation^{4,12,14}.

Recently, Sherman and Lamb stressed the need for reliable reports concerning the dietary habits of athletes, especially elite swimmers¹². The purposes of this study therefore were to collect information regarding the dietary habits of male and female age-group swimmers and to report the energy consumptions of these athletes in relation to their training demands.

Methods

Subjects and training

Twenty competitive swimmers participated in this investigation after signing informed consent¹⁵. All swimmers were familiar with physiological, anthro-

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pometric and dietary testing procedures, having served as subjects in several previous studies^{16,17}. The performance characteristics of this group have been detailed elsewhere¹⁶. Subjects were swimming on average 6000 m per day, 6 days a week, with 75% of this training performed as interval sessions.

Dietary analysis

All subjects were given verbal and written instructions on how to record all fluid and food consumed. Food and fluid were weighed by subjects using conventional standard measuring techniques¹⁴. Diets were recalled by subjects each day for four consecutive training days which included 1 day of the weekend. In addition, subjects were requested to note the frequency of feedings and any extra vitamin or mineral supplementation. No subjects had known food allergies or were taking prescription medication at the time of investigation.

Dietary records were analysed using a commercial computer program (N-Squared Nutritionist, Silverton, Oregon, USA) as previously reported¹⁸. The database of this program was extensively enlarged to include unusual or exotic foods commonly consumed in Australasia, yet not contained in the original program.

Anthropometric data

Lean body mass and relative body fat were estimated from the regression equations of Russo and Wade¹⁹.

Estimation of energy expenditure

The energy cost of activities such as swimming or cycling is difficult to estimate accurately because the energy cost for a given distance covered is a direct function of the movement velocity. There may also exist gender differences in the energy cost of swimming^{20,21}, although a recent study concluded that there were no sex differences in the oxygen demand of front crawl swimming²².

The energy expenditure of swim training is a function of the amount of oxygen consumed and the time spent swimming. Brotherhood has reported energy expenditures for endurance training based on an athletes' $\dot{V}O_{2,max}$ and training duration⁴.

The $\dot{V}O_{2,max}$ of our swimmers was estimated from the multiple regression equation of Costill *et al.*²⁰. Mean(s.d.) values for $\dot{V}O_{2,max}$ were 3.0(0.7) litres min^{-1} for males and 2.6(0.2) litres min^{-1} for females. Subjects were swim training 6000 m, or ~ 2.5 h per day. Based on the estimates of Brotherhood⁴, the mean energy expenditure of our swimmers during training was ~ 1600 kcal (6.7 MJ) daily. For the males, energy expenditure during non-training periods was estimated²³ at 1354(217) kcal (5.7(0.9) MJ) daily. The corresponding value for the females was 1286(270) kcal (5.4(1.1) MJ) daily. Thus, the total daily energy requirements were estimated at 2954 kcal (12.4 MJ) for male swimmers and 2886 kcal (12.1 MJ) for female swimmers.

Statistical analysis

Data were analysed by the computer software package SYSTAT (SYSTAT Inc, Evanston, Chicago, Illinois, USA) with results being considered significant if $P < 0.05$. All values are reported as means(s.d.).

Results

The physical characteristics of the swimmers are shown in Table 1.

Table 2 displays the daily nutrient intakes of swimmers. Although the mean values for most nutrients analysed exceeded RDA²³, a number of swimmers fell below the suggested allowances for a variety of nutrients. Eleven swimmers (55%) reported calcium intakes below the RDA, while 13 swimmers (65%) had iron intakes lower than the recommended allowance. For female swimmers, the mean iron intake was significantly lower ($P < 0.05$) than the RDA with 82% of females having intakes below the recommended level.

Table 3 shows the energy intake and nutrient breakdown for the swimmers. Despite identical training loads and body mass, male swimmers had significantly greater energy consumption than females, whether expressed in absolute terms ($P = 0.004$) or relative to body weight ($P = 0.025$).

Table 1. Physical characteristics of swimmers

	Age (years)	Body mass (kg)	LBM (kg)	Body fat (%)
Males (n=9)	13.2(1.4)	56.4(9.0)	45.7(8.4)	19.0(5.4)
Females (n=11)	13.1(1.9)	56.3(11.9)	42.5(6.1)	24.4*(4.0)

Values are mean(s.d.); LBM, lean body mass

* Significantly greater than males ($P < 0.05$)

Table 2. Daily nutrient intakes of swimmers

Nutrient	Males (n=9)	RDA	Females (n=11)	RDA
Calcium (mg)	1418.0 (499.0)	1200.0 [3]	1012.5 (561.7)	1200.0 [8]
Iron (mg)	20.3 (7.4)	18.0 [4]	14.4* (3.9)	18.0 [9]
Niacin (mg)	26.7 (12.6)	18.0 [3]	18.1 (4.7)	15.0 [3]
Phosphorus (mg)	1892.0 (597.4)	1200.0 [1]	1360.7 (450.8)	1200.0 [4]
Riboflavin (mg)	2.5 (0.8)	1.6 [0]	1.6 (0.7)	1.3 [4]
Thiamine (mg)	2.2 (0.7)	1.4 [1]	1.6 (0.4)	1.1 [1]
Vitamin A (IU)	11294.0 (4390.0)		7962.0 (4566.0)	
Vitamin C (mg)	260.0 (141.0)	50.0 [0]	208.0 (106.0)	50.0 [0]

Values are mean(s.d.). RDA, Recommended dietary allowance²³. Values in square brackets denote number of swimmers below RDA

* Significantly lower ($P < 0.05$) than RDA

The amount of carbohydrate ingested by the male swimmers was significantly greater ($P = 0.011$) than by the females. Female swimmers consumed significantly less ($P = 0.004$) fat than did the males. There were no significant differences between the male and female swimmers with regard to protein intake.

Table 4 displays the contribution of carbohydrate, fat and protein to the swimmers' total daily caloric intake. There were no significant differences between male and female swimmers with respect to any of these measures.

Eighteen (90%) of the swimmers reported that they consumed snacks at regular intervals between meals. With regard to additional vitamin or mineral ingestion, four (20%) of the swimmers (three males, one female) were taking oral supplements in addition to their normal diet. These were in the form of multivitamin pills.

Discussion

Few studies in the literature report a full analysis of the intakes of vitamins and minerals consumed by athletes^{24–26}, but when such analyses are under-

taken, results are typically compared against RDAs⁴. RDAs, however, are only estimates of acceptable daily nutrient intakes and, even if an athlete does consume less than the recommended amount of a specific substance, that athlete's diet is not necessarily inadequate for that nutrient³.

Athletes generally consume micronutrients in excess of the RDAs by virtue of their increased energy intake⁴. However, this study shows that a significant proportion of our swimmers had calcium and iron intakes below RDA values. Low iron intakes are common among female athletes^{4, 24, 25, 27} and caloric intakes below 2000 kcal (8.4 MJ) daily are often associated with iron deficiency²⁸. The female swimmers in the present study, however, were consuming in excess of 2000 kcal (8.4 MJ) per day, and none was on a vegetarian diet. Blood analyses were not undertaken in this study for ethical reasons. However, low serum iron and ferritin concentrations are known to be related to low dietary iron intakes²⁹.

The B vitamins should be consumed in proportion to the total energy content of the diet²³. After adjusting the requirements for niacin, riboflavin and thiamine according to the swimmers' increased daily energy intakes, a number of our subjects could be considered deficient in these vitamins.

The male swimmers in this study were taking in 3072(732) kcal (12.9(3.1) MJ) daily, with females consuming 2130(544) kcal (8.9(0.6) MJ). With all subjects training 6000 m daily, the estimated total daily energy expenditure was 2954 kcal (12.4 MJ) for males and 2886 kcal (12.1 MJ) for female swimmers. The males were therefore maintaining energy balance, whereas the females were consuming ~800 kcal (3.4 MJ) less than their estimated daily energy requirements.

Clearly an energy deficit of this magnitude for the female swimmers is unlikely as it would result in an enormous accumulative energy deficit after a sustained (4–6 week) period of training. On the other hand, when one considers the expected energy expenditures of female athletes involved in other sports compared with their reported dietary intakes, then obviously some energy intakes in those sports are also very low. Reports on female runners²⁴, female swimmers²⁶ and female lacrosse players²⁵ have highlighted the likelihood that there may be a consistent under-reporting of food intake by female athletes⁴. Thus, the low values reported for food intake by the female swimmers in the current study may be due to either (1) an artifact in the method of dietary assessment resulting in under-reporting of nutrient intake, or (2) an over-estimation of daily energy expenditure.

In contrast to strength-trained athletes, endurance-trained athletes typically consume more than 50 kcal kg⁻¹ body weight (0.2 MJ kg⁻¹) per day⁶. The male swimmers in this study were consuming 55(14) kcal kg⁻¹ (0.2(0.1) MJ kg⁻¹), while females were intaking 40(16) kcal kg⁻¹ (0.2(0.1) MJ kg⁻¹). The value for the latter group is in close agreement with the results of Smith *et al.*²⁶ who reported daily energy intake of 39 kcal kg⁻¹ (0.2 MJ kg⁻¹) for female college swimmers. Short and Short²⁵ report caloric intakes ranging from 2267 to 5874 kcal (9.5–24.7 MJ) for

Table 3. Daily energy intakes and nutrient breakdown of swimmers

Energy unit or nutrient	Males (n=9)	Females (n=11)	Significance
kcal	3072.0 (732.0)	2130.0 (544.0)	$P = 0.004$
MJ	12.9 (3.0)	8.9 (0.6)	$P = 0.004$
kcal kg ⁻¹ BM	55.0 (14.0)	40.0 (16.0)	$P = 0.044$
MJ kg ⁻¹ BM	0.3 (0.1)	0.2 (0.1)	$P = 0.044$
Carbohydrate (g)	404.0 (88.0)	292.0 (87.0)	$P = 0.011$
Carbohydrate (g kg ⁻¹ BM)	7.3 (1.7)	5.5 (2.5)	$P = 0.025$
Fat (g)	102.0 (32.0)	63.0 (20.0)	$P = 0.004$
Protein (g)	108.0 (38.0)	79.4 (24.0)	n.s.
Protein (g kg ⁻¹ BM)	1.9 (0.6)	1.5 (0.6)	n.s.

Values are mean(s.d.); BM, body mass; n.s., not significant

Table 4. Percentage contribution of carbohydrate, fat and protein to the total daily energy intake of swimmers

Nutrient	Males (n=9)	Females (n=11)
Carbohydrate	55.0(7.0)	56.0(6.0)
Fat	30.4(6.3)	28.0(4.3)
Protein	15.0(2.7)	16.2(3.4)

Values are mean(s.d.)

female members of a college swim team but, unfortunately, the body weights of the swimmers were not disclosed.

With regard to energy source, carbohydrate provides, on average, ~46% of the energy consumed by athletes⁶. However, the range is wide, and values as high as 60% have been reported for a group of well-trained runners²⁹ and for elite triathletes³⁰. Short and Short reported that 43% of total energy intake was derived from carbohydrate in female swimmers²⁵. A somewhat higher value (49%) was found by Smith *et al.* for competitive female college swimmers²⁶. In the present study the relative contribution of carbohydrate to total caloric intake was 55(7)% and 56(6)% for male and female swimmers respectively.

The male swimmers in this study were consuming significantly greater amounts of carbohydrate than the females, whether expressed in absolute terms ($P = 0.011$), or relative to body mass ($P = 0.025$). Our females were intaking $5.5(2.5) \text{ g kg}^{-1}$, a value slightly higher than that found by Smith *et al.*²⁶, who reported a daily intake of 4.7 g kg^{-1} for female college swimmers training 7300 m per day. Costill and Miller⁷ recommend a diet which provides $\sim 7 \text{ g CHO kg}^{-1} \text{ day}^{-1}$. Thus, the females in the current study could be considered deficient in daily carbohydrate intake.

With regard to fat consumption, males were deriving 30(6)% of their total energy intake from this source, while the figure for females was 28(4)%. These values are lower than those reported in previous studies^{25, 26, 31} on swimmers.

The protein content of athletes' diets usually accounts for ~14 to 16% of energy intake, with athletes involved in endurance sports typically having lower protein intakes than athletes engaged in strength or power events⁴. The contribution of protein to the total energy intake did not differ significantly for males (15(3)%) and females (16(3)%) in the current study. Smith *et al.*²⁶ report an intake of 1.4 g kg^{-1} for female swimmers, which is almost identical to our value. Lemon *et al.*³² recommend a protein intake of 2 g kg^{-1} for individuals engaged in strenuous activities, which is in close agreement with the value of $1.9(0.6) \text{ g kg}^{-1}$ for our male swimmers.

Only four (20%) of the swimmers studied were taking any form of vitamin or mineral supplementation. Analyses of these individual diets revealed that these swimmers were exceeding RDAs for all micronutrients studied without supplementation. A recent double-blind, cross-over, placebo-controlled study²⁹ concluded that multivitamin and mineral supplementation was without any measurable ergogenic effect and unnecessary in athletes ingesting a normal diet.

Ninety per cent of the swimmers in our investigation reported eating snacks between meals. These were usually in the form of simple sugars (confectionery, soft drinks, biscuits, etc.). Previous studies^{6, 33} have demonstrated that muscle glycogen synthesis is the same when athletes consume either simple or complex carbohydrate for the first 24 h after prolonged exercise. Thus the consumption of simple sugars between training bouts, as practised by the majority of the swimmers in the current study, may

be beneficial with regard to the day to day resynthesis of muscle glycogen stores.

In conclusion, there were several important findings in this study. Firstly, a significant proportion of our swimmers had calcium and iron intakes below RDA values. Second, despite identical training loads and body mass, male swimmers had greater energy consumptions than females. Male swimmers were, therefore, maintaining energy balance, whereas females were consuming less than their estimated daily energy requirements. In this respect, the amount of carbohydrate ingested by male swimmers was significantly greater than that by the females, and thus the females could be considered deficient in daily carbohydrate intake. These females seem insensitive to daily energy expenditure and have difficulty maintaining recommended carbohydrate and caloric balance. Finally, although 90% of the swimmers reported eating regular snacks between meals, only four (20%) were taking any form of vitamin or mineral supplementation.

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