

# Dietary intakes of age-group swimmers

J. A. Hawley MA and M. M. Williams MSc

School of Physiotherapy, Faculty of Health Studies, Auckland Institute of Technology, Auckland, New Zealand

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 10 000 and 14 000 m per day with a large proportion of this workload being performed at high intensity<sup>1</sup>. The recent development of age-group swimming programmes has resulted in the prescription of severe endurance training regimens for young children<sup>2</sup>.

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<sup>3,4</sup>. 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<sup>5–11</sup>. Indeed, carbohydrate is the preferred fuel for muscle metabolism when the intensity of exercise is >65% of maximal oxygen uptake ( $\dot{V}O_{2, \max}$ )<sup>7,10</sup>. 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 exercise<sup>6</sup>. 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 training<sup>7</sup>.

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

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 habits<sup>4</sup>. 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<sup>4,12,14</sup>.

Recently, Sherman and Lamb stressed the need for reliable reports concerning the dietary habits of athletes, especially elite swimmers<sup>12</sup>. 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 consent<sup>15</sup>. All swimmers were familiar with physiological, anthro-

Address for correspondence: J. A. Hawley, Liberty Life Chair of Exercise Science, MRC/UCT Bioenergetics of Exercise Research Unit, Department of Physiology, University of Cape Town Medical School, Observatory 7925, South Africa

© 1991 Butterworth-Heinemann Ltd.  
0306-3674/91/030154-05

pometric and dietary testing procedures, having served as subjects in several previous studies<sup>16,17</sup>. The performance characteristics of this group have been detailed elsewhere<sup>16</sup>. 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 techniques<sup>14</sup>. 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 reported<sup>18</sup>. 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 Wade<sup>19</sup>.

### 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<sup>20,21</sup>, although a recent study concluded that there were no sex differences in the oxygen demand of front crawl swimming<sup>22</sup>.

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 duration<sup>4</sup>.

The  $\dot{V}O_{2,max}$  of our swimmers was estimated from the multiple regression equation of Costill *et al.*<sup>20</sup>. Mean(s.d.) values for  $\dot{V}O_{2,max}$  were 3.0(0.7) litres  $\text{min}^{-1}$  for males and 2.6(0.2) litres  $\text{min}^{-1}$  for females. Subjects were swim training 6000 m, or ~2.5 h per day. Based on the estimates of Brotherhood<sup>4</sup>, 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 estimated<sup>23</sup> 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 RDA<sup>23</sup>, 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 allowance<sup>23</sup>. 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<sup>24-26</sup>, but when such analyses are under-

taken, results are typically compared against RDAs<sup>4</sup>. 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 nutrient<sup>3</sup>.

Athletes generally consume micronutrients in excess of the RDAs by virtue of their increased energy intake<sup>4</sup>. 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<sup>4, 24, 25, 27</sup> and caloric intakes below 2000 kcal (8.4 MJ) daily are often associated with iron deficiency<sup>28</sup>. 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 intakes<sup>29</sup>.

The B vitamins should be consumed in proportion to the total energy content of the diet<sup>23</sup>. 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 runners<sup>24</sup>, female swimmers<sup>26</sup> and female lacrosse players<sup>25</sup> have highlighted the likelihood that there may be a consistent under-reporting of food intake by female athletes<sup>4</sup>. 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<sup>-1</sup> body weight (0.2 MJ kg<sup>-1</sup>) per day<sup>6</sup>. The male swimmers in this study were consuming 55(14) kcal kg<sup>-1</sup> (0.2(0.1) MJ kg<sup>-1</sup>), while females were intaking 40(16) kcal kg<sup>-1</sup> (0.2(0.1) MJ kg<sup>-1</sup>). The value for the latter group is in close agreement with the results of Smith *et al.*<sup>26</sup> who reported daily energy intake of 39 kcal kg<sup>-1</sup> (0.2 MJ kg<sup>-1</sup>) for female college swimmers. Short and Short<sup>25</sup> 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 <sup>-1</sup> BM	55.0 (14.0)	40.0 (16.0)	$P = 0.044$
MJ kg <sup>-1</sup> 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 <sup>-1</sup> 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 <sup>-1</sup> 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 athletes<sup>6</sup>. However, the range is wide, and values as high as 60% have been reported for a group of well-trained runners<sup>29</sup> and for elite triathletes<sup>30</sup>. Short and Short reported that 43% of total energy intake was derived from carbohydrate in female swimmers<sup>25</sup>. A somewhat higher value (49%) was found by Smith *et al.* for competitive female college swimmers<sup>26</sup>. 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.*<sup>26</sup>, who reported a daily intake of  $4.7 \text{ g kg}^{-1}$  for female college swimmers training 7300 m per day. Costill and Miller<sup>7</sup> 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<sup>25, 26, 31</sup> 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 events<sup>4</sup>. 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.*<sup>26</sup> report an intake of  $1.4 \text{ g kg}^{-1}$  for female swimmers, which is almost identical to our value. Lemon *et al.*<sup>32</sup> recommend a protein intake of  $2 \text{ g kg}^{-1}$  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 study<sup>29</sup> 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<sup>6, 33</sup> 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.

## References

- 1 Costill DL, Fink WJ, Hargreaves M, King DS, Thomas R, Fielding R. Metabolic characteristics of skeletal muscle during detraining from competitive swimming. *Med Sci Sports Exerc* 1985; 17: 339-43.
- 2 Vaccaro P, Clark DH, Morris AF. Physiological characteristics of young well-trained swimmers. *Eur J Appl Physiol* 1980; 44: 61-6.
- 3 Grandjean AC. Nutrition for swimmers. *Clin Sports Med* 1986; 5: 65-76.
- 4 Brotherhood JR. Nutrition and sports performance. *Sports Med* 1984; 1: 350-89.
- 5 Christensen EH, Hansen O. Arbeitsfähigkeit und ernährung. *Scand Arch Physiol* 1939; 81: 160-71.
- 6 Costill DL, Sherman WM, Fink WJ, Maresh C, Witten M, Miller JM. The role of dietary carbohydrates in muscle glycogen resynthesis after strenuous running. *Am J Clin Nutr* 1981; 34: 1831-6.
- 7 Costill DL, Miller JM. Nutrition for endurance sport: carbohydrate and fluid balance. *Int J Sports Med* 1980; 1: 2-14.
- 8 Hawley JA, Nuefer PD. Carbohydrate feedings and endurance performance. *NZ J Sports Med* 1986; 14: 43-6.
- 9 Karlsson J, Saltin B. Diet, muscle glycogen and endurance performance. *J Appl Physiol* 1971; 31: 203-6.
- 10 Saltin B, Karlsson J. Muscle glycogen utilization during work of different intensities. In: Pernow B, Saltin B, eds. *Muscle Metabolism During Exercise*, New York: Plenum Press, 1971: 289-300.
- 11 Sherman WM. Carbohydrate, muscle glycogen and improved performance. *Phys Sportsmed* 1987; 15: 157-64.
- 12 Sherman WM, Lamb DR. Nutrition and sports performance. In: Lamb DR, Murray R, eds. *Perspectives in Exercise Science And Sports Medicine. Volume I: Prolonged Exercise*. Carmel, Indiana, USA: Benchmark Press Inc. 1988, 213-80.
- 13 Wootton S. *Nutrition for Sport*. New York: Facts On File Publisher; 1988: 73-85.
- 14 Durnin JVG, Ferro-Luzzi A. Conducting and reporting studies on human energy intake and output: suggested standards. *Hum Nutr Appl Nutr* 1983; 37A: 141-4.
- 15 American College of Sports Medicine. Policy statement regarding the use of human subjects and informed consent. *Med Sci Sports Exerc* 1989; 21: v.
- 16 Hawley JA, Williams MM. Relationship between upper body anaerobic power and freestyle swimming performance. *Int J Sports Med* 1991; 12: 1-5.
- 17 Hawley JA, Williams MM, Handcock PJ, Vickovic MM. Muscle power predicts freestyle swimming performance. *J Sports Sci* 1991; (in press).

**Dietary intakes of age-group swimmers: J. A. Hawley and M. M. Williams**

- 18 Costill DL, Flynn MG, Kirwan JP, Houmard JA, Mitchell JB, Thomas R, Park SH. Effects of repeated days of intensified training on muscle glycogen and swimming performance. *Med Sci Sports Exerc* 1988; 20: 249-54.
- 19 Russo PF, Wade KJ. The estimation of the percentage of body fat in Australian children using anthropometric measures and body density from hydrostatic weighing. *Transactions from the Menzies Foundation* 1983; 5: 59-81.
- 20 Costill DL, Kovaleski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. *Int J Sports Med* 1985; 6: 266-70.
- 21 Pendergast DR, Di Prampero PE, Craig AB, Wilson DR, Rennie DW. Quantitative analysis of the front crawl in men and women. *J Appl Physiol* 1977; 43: 475-9.
- 22 Monpetit RM, Cazorla G, Lavoie JM. Energy expenditure during front crawl swimming: a comparison between males and females. In: Ungerechts BE, ed. *Swimming Science V*. International Series on Sport Sciences. Human Kinetics Publications, Illinois 1985; 18: 229-35.
- 23 Burtis G, Davis J, Martin S. *Applied Nutrition and Diet Therapy*. Philadelphia: WB Saunders, 1988.
- 24 Dale E, Goldberg DL. Implications of nutrition in athletes' menstrual cycle irregularities. *Can J Appl Sport Sci* 1982; 7: 74-8.
- 25 Short SH, Short WR. Four-year study of university athletes' dietary intake. *J Am Diet Assoc* 1983; 82: 632-45.
- 26 Smith MP, Mendez J, Druckenmiller M, Kris-Etherton PM. Exercise intensity, dietary intake and high-density lipoprotein cholesterol in young female competitive swimmers. *Am J Clin Nutr* 1982; 36: 251-5.
- 27 Newhouse IJ, Clement DB. Iron status in athletes: an update. *Sports Med* 1988; 5: 337-52.
- 28 Clement DB, Sawchuk LL. Iron status and sports performance. *Sports Med* 1984; 1: 65-74.
- 29 Weight LL, Noakes TD, Labadarios D, Graves J, Jacobs P, Berman PA. Vitamin and mineral status of trained athletes including the effects of supplementation. *Am J Clin Nutr* 1988; 47: 186-91.
- 30 Burke LM, Read RSD. Diet patterns of elite Australian male triathletes. *Phys Sportsmed* 1987; 15: 140-55.
- 31 Saltin B. Fluid, electrolyte, and energy losses and their replenishment in prolonged exercise. In: Parizkova P, Rogozkin F, eds. *Nutrition, Physical Fitness and Health*. Baltimore: University Park Press, 1978: 76-97.
- 32 Lemon PWR, Yarasheski KE, Dolny DG. The importance of protein for athletes. *Sports Med* 1984; 1: 474-84.
- 33 Roberts KM, Noble EG, Hayden DB, Taylor AW. Simple and complex carbohydrate-rich diets and muscle glycogen content of marathon runners. *Eur J Appl Physiol* 1988; 57: 70-4.