# Marathon and 50km walk race: physiology, diet and training

© by IAAF
11:4; 51-58, 1996

by Enrico Arcelli

*By plotting on a graph the average speeds of the world record performances, from 400 metres to beyond the marathon, a curve is obtained which shows that speed decreases regularly up to the half marathon distance. However, its projection up to the marathon suggests that the speed for this event should be higher than that of the present world record. The reason for this discrepancy, in the author' view, has to do with the energy supply in the different events. With this in mind, an investigation is made of the different ways in which energy is supplied and expended in the various races.*

*A description is given of the roles played by carbohydrates and by lipids in supplying energy for the marathon and longer distance events, such as the 50km walk, and recommendations are made regarding the best training speed to ensure an optimum use of these nutrients.*

*Enrico Arcelli is a graduate in medicine and surgery with specialization in nutrition, sports medicine and physiology of sport and exercise. He is a professor of sports medicine at the University of Siena, Italy. He is also an athletic coach and he was for many years head coach of middle and long distances and race walking in the Italian athletic federation FIDAL.*

## 1 Introduction

The particular physiological characteristics of specialists in the marathon and in the 50km walk significantly influence certain aspects of their ideal diet. It may be interesting to take into account also shorter and longer distances, so as to have a more comprehensive view of this issue.

## 2 World record performances in running events from the 400m to the 100km

On the basis of the men's world records for distances from the 400m to beyond the marathon, i.e. including the 100km, which is attracting an increasing number of participants, we can calculate the average speed, expressed in kilometres per hour (km/h; column 3, *Table 1*). The curve obtained by plotting these values on a graph, as the logarithmic function of the duration of the race, is shown in *Figure 1*. We can observe that the speed decreases very regularly up to the distance corresponding to the half marathon. The extrapolation of the curve, where

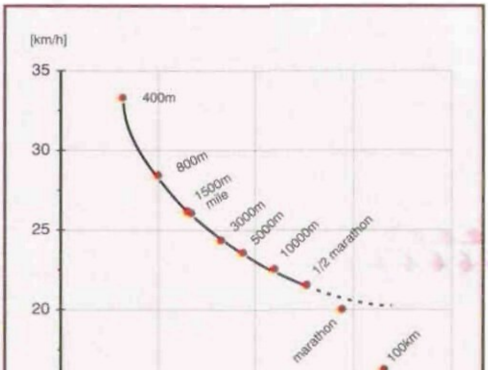


**Figure 1: Average speed referred to men's world records in running events from 400m to 100km** (in kilometres per hour) as a function of the duration of the race (in seconds – logarithmic scale)

it corresponds to the marathon race (dotted line), indicates an average speed of 20.6 km/h, which is significantly higher than the average speed, 19.961 km/h that produced the present world record performance, achieved by the Ethiopian runner Belayme Dinsano (2:6:50h, Rotterdam 17.4.1988).

## 3 Why the difference?

It has been suggested that the world record for the marathon is inferior to the records for the longer middle distance races (5 to 10,000m). I do not agree. Belayme ran under favourable conditions and quite a number of international level athletes have since tried to better his performance and failed. In my opinion, the reason for this difference is to do with the energy supply in the different events.

## 4 Energy expenditure and average power in flat running and race walking

We may say that energy expenditure in the various flat races, expressed in ml/kg, i.e. millilitres of oxygen per kilogram of bodyweight, is the sum of the following three components, where **d** is the distance in kilometres, and **v** the speed in kilometres per hour (ARCELLI 1976):

- energy expenditure to cover the distance at constant speed; assuming the athlete is not facing air resistance, the value is about 175d;
- energy expenditure to overcome air resistance, equal to $0.037dv^2$;
- energy expenditure for initial acceleration, equal to $0.0046v^2$.

These values allow us to calculate energy expenditure corresponding to world record performances for each of the distances considered. The value obtained, divided by the time clocked (expressed in minutes and decimal fractions) indicates the average power achieved by the respective world record holders (last column *Table* 1).

Similar calculations can be applied to the world record performances in the men's walking races, in particular to the 5,000m, the distance for most indoor events, and the 20 and 50km races, the distance for most international events, including the Olympic Games. In walking races, energy expenditure expressed in millilitres of oxygen per kilogram of body weight per minute (ml/kg/min) is given by the following formula (ARCELLI and LA TORRE 1994a, 1994b):

$$6.86v - 38.8$$

where v is the athlete's speed. The values for average power obtained with this method are shown in *Table 2* (last column), together with the world records and the average speed for each of the three races considered.

In *Figure 2* the average power for the various distances are placed in relation to the logarithm of the duration of each race, expressed in seconds. Here again, we can observe that the curve shows a regular decrease up to a certain point – to be exact, up to the value corresponding to the 20km walking race, while the values corresponding to the longer distances (marathon, 50km walking race and 100km race) are not in line with the extrapolation of the curve.

I believe the peculiarities highlighted in *Figure 2* may be explained by the fact that all the running and walking races having a duration equal to that of the 20km walking race may be completed

**Table 1: Average speed** (in kilometres per hour – km/h) **and average power** (in millilitres of oxygen per kilogram of bodyweight per minute – ml/kg/min) **calculated from men's world record performances** (standing April 1st 1996) **in running events from the 400m to the 100km races**

| Event | World record [hour:min:sec] | Average speed [km/h] | Average power [ml/kg/min] |
|---|---|---|---|
| 400m | 43.29 | 33.264 | 126.8 |
| 800m | 1:41.73 | 28.310 | 98.7 |
| 1500m | 3:27.37 | 26.040 | 87.7 |
| mile | 3:44.39 | 25.819 | 86.7 |
| 3000m | 7:25.11 | 24.264 | 79.9 |
| 5000m | 12:44.39 | 23.548 | 76.9 |
| 10,000m | 26:43.53 | 22.450 | 72.5 |
| half marathon | 58:51. | 21.510 | 68.7 |
| marathon | 2:06:50. | 19.961 | 64.9 |
| 100km | 6:10:20. | 16.202 | 49.9 |

**Table 2: Average speed** (in kilometres per hour – km/h) **and average power** (in millilitres of oxygen per kilogram of bodyweight per minute – ml/kg/min) **calculated from men's world record performances** (standing April 1st 1996) **in the race walking events**

| Event | World record [hour:min:sec] | Average speed [km/h] | Average power [ml/kg/min] |
|---|---|---|---|
| 5,000m | 18:07.08 | 16.558 | 74.8 |
| 20,000m | 1:17:25.6 | 15.501 | 67.5 |
| 50,000m | 3:41:28.2 | 13.288 | 52.4 |

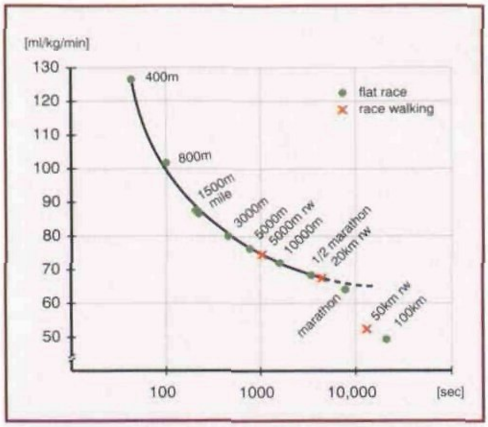


**Figure 2: Average power** (in millilitres of oxygen per kilogram of bodyweight, per second) ***as a function of the duration of the race*** (*in seconds – logarithmic scale*) **referring to men's world records in running events from 400m to 100km and to the 5km, 20km and 50km walking races**

using only muscle and liver glycogen, apart from any carbohydrates ingested during competition. This is not possible for the longer races. Indeed, *according to* O'BRIEN *et al. (1993), during competition* an athlete can consume a maximum of about 475 grams of glycogen, 375g of which are supplied by the muscles and 100g by the liver. Since each gram of glycogen produces about 4 kilocalories, muscle and liver deposits can provide 1900 kilocalories. For an athlete weighing 70 kilograms, energy expenditure to complete a 20km walking race is slightly higher than 1900 kilocalories, but it is definitely much higher for the longer distances.

## 5 How to favour carbohydrate consumption during long distance races

The above considerations indicate that, for marathon runners and the 50km race walkers (and of course also for athletes who compete in longer distances), it would be a great advantage to obtain a larger percentage of energy from carbohydrates. This may be achieved by increasing:

- the amount of carbohydrates stored in the body and made available during competition, (i.e. increased muscle glycogen);
- carbohydrate intake during competition.

As regards the former, many of the considerations put forward by Scandinavian researchers in the late sixties are still valid. They suggested that higher levels of muscle glycogen can be achieved by performing a very prolonged training session 6-7 days before competition, so as to empty the muscle glycogen stores. This effect would be enhanced by a glycoprivative diet for three days, followed, for another three days (those immediately preceding competition) by a high carbohydrate diet (*Table 3*). Nowadays, distance runners, even those who follow a mixed diet, have muscle glycogen levels that are much higher than those of non-exercising individuals and, in consideration of the fact that it is difficult to follow a low carbohydrate diet, the first phase could be shortened to a single day, or even skipped.

As regards the ingestion of carbohydrates (or of other substances that would supply energy to the muscles) during the longer races, we should remember that, as the intensity of the effort increases, calorie intake becomes that much more difficult (COSTILL and SALTIN 1974). In the case of marathon runners, calorie intake is usually limited to a few dozen calories, because runners do not drink at every one of the refreshment points, unless heat and humidity are such that they sweat profusely, and they seldom drink more than 100-150 millilitres at a time, preferring plain water or other liquids with low carbohydrate concentration. The 50km walk is longer than the marathon and the refreshment points are closer together; athletes can, therefore, drink more and calorie intake is consequently higher, but it still remains insufficient.

**Table 3: Characteristics of the diet recommended in the late sixties by Scandinavian researchers; it favours a significant increase in muscle glycogen concentration** (ARCELLI 1989)

- The diet was divided into two three-day periods.
- During the first three days (from the sixth to the fourth day before competition), the athlete followed a glycoprivative diet, i.e. mainly proteins and fats, no carbohydrates.
- During the three days before competition, the athlete changed to a high carbohydrate diet.
- Furthermore, during the first period, the athlete continued training; in particular, on the sixth or seventh day before competition, he/she performed a prolonged, intense training session, so as to empty the muscles of glycogen and favour their subsequent over-filling.
- *During the second period (last three days), the athlete followed only light training sessions so as not to expend glycogen.*
- According to SALTIN and HERMANSEN, this diet raised the amount of glycogen in the muscles from the usual 1.3-2g per 100g of muscle to over 3g. More recent studies show that trained marathon runners today have basal values of over 2.5g of glycogen per 100g of muscle.
- The most appropriate foodstuffs for the high carbohydrate diet of the last three days before competition are: pasta, rice, bread, low fat crackers, cookies and pastries without cream or custard, nuts (except oily ones such as walnuts, hazel nuts, peanuts, almonds), peas and beans, vegetables, honey, jam, sweets, soft drinks (cola, juice...), low fat milk.

The stomach occupancy time of ingested liquids is the limiting factor as regards carbohydrate intake in the unit of time during competition. About 15-20 gm of plain water transit through the stomach in one minute (DAVEMPORT 1982); liquids containing salt, or even more so sugar, tend to be slower; liquids with a carbohydrate concentration lower than 5% transit through the stomach at a rate close to that of plain water (MAUGHAM and NOAKES 1991). As the sugar concentration in a liquid increases, so does stomach occupancy time. According to COSTILL and SALTIN (1974), for liquids with a glucose concentration ranging between 2.5 and 15%, stomach occupancy time is such that calorie intake is about 2.5 kcal/min. When the solution contains maltodextrine or fructose instead of glucose or saccharose, the rate is slightly higher (MORAN and MCHUGH 1981).

## 6 Energy supply in the marathon

We may say that, from the point of view of energy supply, the marathon race and the 50km walk have two "souls": one glucosidic the other lipidic; both are important and cannot be neglected.

Using the formula indicated above for flat races, we can establish that the quantity of energy needed to complete a marathon race is about 8.05 litres of oxygen per kilogram of bodyweight. For an athlete weighing 70 kilos, this corresponds to a total of 563.5 litres of oxygen, equal to 2,820 kilocalories. As we mentioned earlier, according to O'BRIEN et al. (1993) only 1900 kilocalories can be supplied by muscle and liver glycogen, and, particularly in the case of high level marathon runners, carbohydrate intake during competition (or intake of other substances that may be used by the muscles) is very low, corresponding to a few dozen calories at most. Also muscle protein consumption is not significant, especially in high level athletes. The lipids already stored in the body at the start of the race must therefore supply the remaining energy requirement. The energy supplied by these lipid stores covers the major part of the difference between total energy expenditure and glycogen supplied energy, i.e.:

$$2820 \text{ kcal} - 1900 \text{ kcal} = 920 \text{ kcal}$$

Since 1 gram of lipids provides about 9kcal, a marathon runner consumes about 100 grams of lipids during the race, or a little less if he ingests energy providing substances during the race. On the basis again of O'BRIEN et al.'s data (1993), lipids provide one third of the energy required to complete a marathon race. Of the remaining two thirds, over 30% is supplied by muscle glycogen and just under 15% by liver glycogen (*Table 4*).

The difference between the value obtained through extrapolation of the curve in *Figure 1* and the average speed corresponding to the present world record for the marathon race (20.6km/h against 19.961km/h) may quite possibly be due to the fact that part of the energy requirement in the marathon race is not covered by carbohydrates. Lipids provide 7.7% less energy than carbohydrates, the quantity of oxygen used remaining constant. Also, and this may be the more significant difference, the lipid combustion mechanism, what may be defined as the "aerobic-lipidic" mechanism (ARCELLI and LA TORRE 1994a, 1994b), produces a smaller quantity of energy per minute than the carbohydrate combustion mechanism. In other words, the power of the aerobic-lipidic "engine" is lower than that of the aerobic glucosidic one.

This may also explain why – as shown in *Figure 2* – the average power recorded for races lasting longer than the 20km walk (marathon, 50km walk race and 100km) differs from values calculated through extrapolation of the curve from the 400m flat race to the 20km walk race. The energy requirement for these longer races increases progressively and so does the amount of energy supplied by lipids.

## 7 Lipid consumption in the marathon race

Athletes having the same bodyweight require the same amount of energy to complete a marathon race, even when one is a high level runner and the other takes much longer to cover the 42.2km. Contrarily to what one may think, a high level runner's total energy expenditure is similar to that of less able runners; indeed, it may even be lower, since the increase of the cost of overcoming air resistance is not significant and is compensated for by the fact that high level runners usually have better movement economy.

As regards energy supply, it is very likely that less talented or less well trained runners have lower levels of muscle glycogen, but since their

**Table 4: Energy supply in the marathon race**

The calories (and the percentage of total energy expenditure) deriving respectively from muscle glycogen, liver glycogen and lipids are calculated from data on total energy expenditure in a marathon race and from O'Brien's data on glycogen consumption (O'BRIEN et al. 1993). It is assumed that carbohydrate intake during the race and protein consumption by the muscles are both nill. Glycogen provides 67.4% of the energy requirement of a marathon race.

| Energy supply | g | kcal | % |
|---|---|---|---|
| muscle glycogen | 375 | 1500 | 53.2 |
| liver glycogen | 100 | 400 | 14.2 |
| lipids | 102 | 920 | 32.6 |
| *total* | | 2820 | 100.0 |

running speed is lower and it takes them longer to cover the distance, the total energy supplied by carbohydrates in their case may be slightly higher than for the better performers. The overall value of lipids consumed, 100g, probably does not change.

On the basis of this datum, we may calculate that, for a performance ranging between the world record and 2:12h, lipid consumption is equal to 0.75 - 0.80g/min; it is below 0.55g/min when the time clocked is over 3 hours. This index, lipid consumption per unit of time, is certainly very significant (ARCELLI and LA TORRE 1994a, 1994b). Lipid consumption is not constant. It is lower at the beginning and increases in the course of the race. Such an increase is more conspicuous in the less proficient runners, who do not ingest carbohydrates during the race. It produces a decrease in running speed, especially after about three hours (COYLE 1991).

Even though the total amount of energy supplied by lipids is lower than that supplied by carbohydrates, as maintained by O'BRIEN et al. (1993), lipid consumption, especially lipid consumption in the unit of time, must be taken into account.

## 8 Energy supply and lipid consumption in the 50km walk

The aspects examined above are even more interesting in the case of the 50km walk. *Table 5* shows lipid consumption (expressed in kilocalories, total grams and grams per minute) for an athlete weighing 65kg, who covers the distance in a time ranging from 3:35:00 to 4:20:00h. It must be noted that, in the 50km walk as opposed to the marathon, energy expenditure (re. the formula given above), increases significantly as the speed increases. Indeed, an athlete who covers 50km in 4:20:00h (average speed 11.538km/h) has an energy expenditure of about 40ml/kg/min, while, for an athlete whose time is 3:35:00h (average speed 13.959 km/h), energy expenditure is nearly 40% higher, at about 57ml/kg/min. However, it is important to keep in mind that the

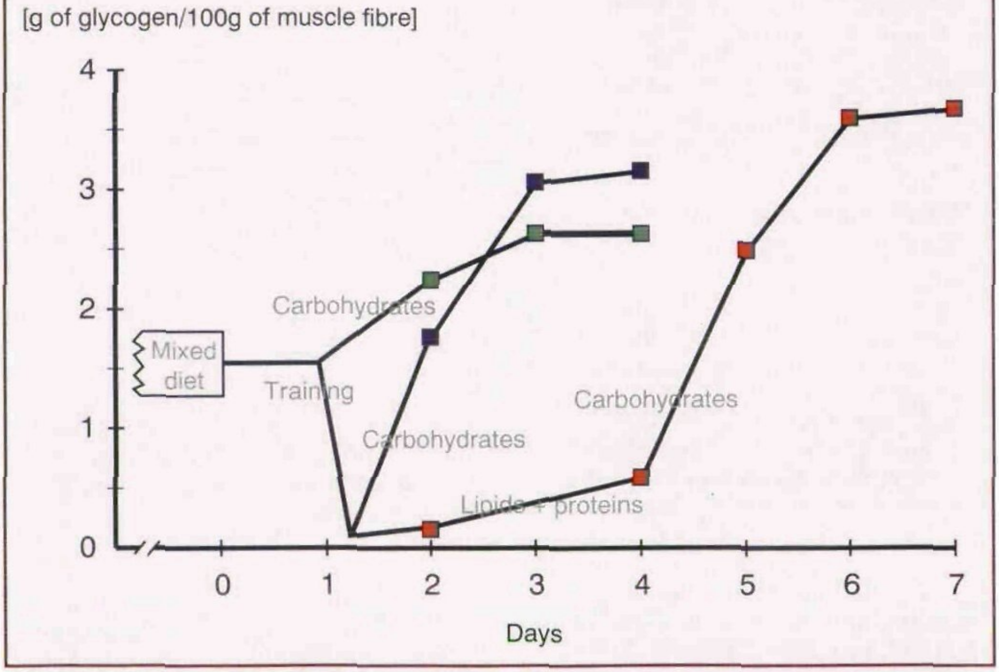


**Figure 3: Variations in the muscle glycogen concentration (in grams of glycogen per 100gm of fresh muscle fibre) as a function of level of training and type of diet**

Sufficiently prolonged and intense training can reduce muscle glycogen concentration up to near total exhaustion. A three-day low-carbohydrate diet, rich in proteins and lipids (indicated as "lipids + proteins") limits repletion, while the subsequent three-day high-carbohydrate diet (indicated as "carbohydrates") favours a significant increase of muscle glycogen levels. The highest levels are obtained after muscle stores have been emptied by a prolonged training session, the athletes follows a glycoprivative diet for three days and then a high-carbohydrate diet for another three days (FROM: SALTIN & HERMANSEN, 1967; quoted by ASTRAUD & RODALH 1970; modified).

**Table 5: Lipid consumption in a 50km walking race**

For performances ranging from 3:35 to 4:35, for an athlete weighting 65 kilograms, the table indicates lipid consumption expressed as total kilocalories, total grams, and, in the last column, as grams per minute (ARCELLI and LA TORRE, 1994a).

| Performance time in h:min | Lipid consumption in a 50km walking race kcal | g | g/min |
|---|---|---|---|
| 4:20 | 1510 | 165 | 0.63 |
| 4:10 | 1630 | 180 | 0.73 |
| 4:00 | 1760 | 195 | 0.81 |
| 3:50 | 1890 | 210 | 0.91 |
| 3:45 | 1950 | 220 | 0.98 |
| 3:40 | 2010 | 225 | 1.02 |
| 3:35 | 2080 | 230 | 1.07 |

differences in energy expenditure between walkers, especially at higher speeds, may be much more significant than the differences between marathon runners.

However, in walking races, when the energy expenditure values are similar, there is little difference in total carbohydrate consumption during the race between the faster and the slower athletes. In fact, the latter can consume more carbohydrates, since it takes them longer to cover the distance. This is why the better performances entail such an increase in lipid consumption per minute (*Table 5*). As mentioned earlier, a performance limiting factor may be the reduced power of the aerobic-lipidic mechanism; in other words, the fact that a high rate of lipid consumption is difficult to achieve. We may therefore say that it could be advantageous to undertake specific training to develop this particular mechanism, and we shall deal with this further on.

## 9 Origin of the lipids used by muscles

The lipids used by an athlete's muscles during a 50km race walk may be provided by (ARCELLI and LA TORRE 1994a, 1994b):

- triglyceride droplets that are contained in the muscle fibres before the beginning of the race ( specific training for the longer distances increases the level of these triglycerides);
- lipoproteins in the blood;
- triglycerides contained in adipose cells. These cells, present in the whole body, but particularly in subcutaneous tissue and between the abdominal organs, represent the larger part of the body's lipid stores. Even in lean athletes these stores are sufficient to cover all requirements.

Most of the lipids used by walkers during a 50km walk are supplied by adipose cells. Triglycerides as such cannot leave the adipose cells (*Figure 4*), but the beginning of physical exercise, such as the warm-up before competition, causes changes in the blood concentration of various hormones: Adrenalin, arterenol, glucagon and somatotropin increase, while insulin decreases. This favours lipolysis, i.e. the process by which the triglyceride molecule is split into the four elementary molecules, one of glycerol and three of free fatty acids (FFA). These then leave the adipose cell (*Figure 5*) and are carried in the blood by a protein molecule, albumin, to the muscle fibres, where they will be used within mitochondria.

What is the limiting factor in regard to the quantity of lipids derived from adipose cells that can be used by muscles in the unit of time?

According to LAMB (1984) the limiting factor is the concentration of FFA in the blood. According to NEWSHOLME (1989) it is the time required to cross the space between the blood vessel and the inner part of the muscle fibre. It is necessarily a slow process because FFA are not soluble in an environment as watery as the extracellular liquids. This is why the difference of FFA concentration in extracellular liquids and in muscle fibre cytoplasm, the "concentration gradient", may be very important, as well as the activity of the enzymes governing FFA utilisation within the muscle fibres. As the speed at which FFA are used (and so disappear) within the sarcoplasm increases, the passage of FFA from extracellular liquids to muscle fibres becomes easier.

It can be assumed that specific training for the marathon or for the 50km walk both increases an athlete's muscle lipid stores and also favours the passage, and utilisation, of FFA derived from adipose cells.

There is no reason to believe that distance runners should consume larger quantities of lipids than non-exercising individuals. The percentage of body fat in marathon runners and race walkers is very low (about 3-6% of body weight, i.e. 3.5-4kg for an athlete weighing 65-70kg), but it is sufficient to cover the requirements of even the longest distances. One kilogram of lipids provides about 9000kcal, which corresponds to the amount of energy that would be used by an ath-

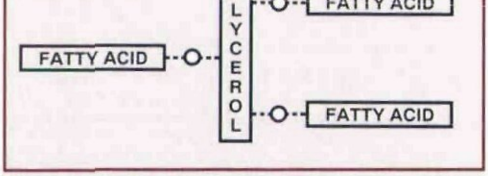


**Figure 4: The triglyceride molecule, composed of four elementary molecules, is split up by lipolysis: one glycerol molecule and three fatty acid cells**

lete weighing 70kg to run 150km or walk 120km at 12km/h, if he were to exploit only the energy supplied by lipids. In other words, even a very lean athlete can run a very long way using only lipid-supplied energy!

## 10 Training speed for 50km race walkers

In regard to training specifically aimed at the 50km walking race, we must say that even the specialists perform a relevant amount of training at higher speed, because they often compete in 3km indoor events in the winter and 5 or 10km track events in the summer. They are not true 50km specialists since they train at higher intensities, so as to be ready also for the shorter races. In order to be prepared to cover the whole 50km, they also perform lengthy training sessions at a slower rhythm, significantly slower than that used in a 50km walking race.

I believe the best way to stimulate lipid consumption is to train at the speed that requires the highest possible lipid consumption per unit of time. Note that, although lower walking speeds, for instance lower than 10km/h, may entail a higher percentage lipid consumption, the maximum level of lipid consumption per unit of time, as shown in *Figure 6*, is achieved at intermediate speeds. *Figure 6* refers to an athlete who, a few months before the test, covered the 50km at a speed of over 13.3km/h, thus winning the silver medal at the World Championships. The test was performed when the athlete was not at the top of his form, but we can observe that the maximum lipid consumption rate corresponds to a walking speed ranging between 12 and 13km/h. Lipid consumption decreases very swiftly as speed increases and approaches that at which energy is prevalently supplied by carbohydrates. The decrease is slower when the walking speed is lower than 12-13km/h. In these specific conditions, i.e. for this particular athlete, at this particular stage of training, we can assume that the walking speed best suited to train his lipid consumption capacity ranges between 12 and 13km/h. Lower speeds would not be as efficient and higher ones even less so. As we can see in *Figure 6*, a walking speed of about 15km/h produces a blood lactate level of about 5mmol/l and might, therefore, be useful as a training means to raise the anaerobic threshold. Higher speeds produce a very high blood lactate concentration and tend to inhibit lipid consumption.

These tests may be used to identify the walking speed that should be maintained for a considerable distance during training sessions specifically aimed at the 50km walk race.

It has been mentioned earlier that, in the marathon race, even the better athletes do not have lipid consumption rates as high as those recorded for 50km race walkers. However, tests similar to those examined here could prove useful also for marathon runners. To increase the quantity of lipids consumed per unit of time, they would have to train at a speed that requires the highest lipid consumption rate. This speed is probably slightly lower than marathon competition speed. We may assume that, also for marathon runners, training at a speed entailing a high blood lactate concentration would inhibit lipid consumption.

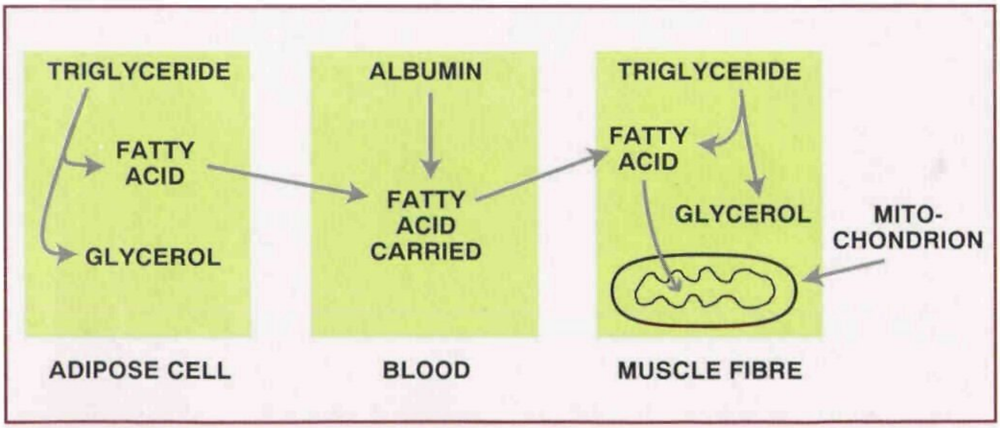


**Figure 5: Simplified diagram showing how triglycerides are used within the muscle fibre**
Lipolysis splits triglycerides in the adipose cell (left) into the four elementary molecules: one glycerol molecule and three fatty acid cells. These three are released into the blood (centre), tied to albumin and carried to the muscle fibres. When inside the muscle fibre (right) the fatty acid cells are split into fragments, each of which contains two carbon atoms; the combustion is completed in the mitochondrion. A certain amount of fatty acids are supplied by triglycerides stored in the muscle fibres; such stores increase after long periods of specific long distance training.

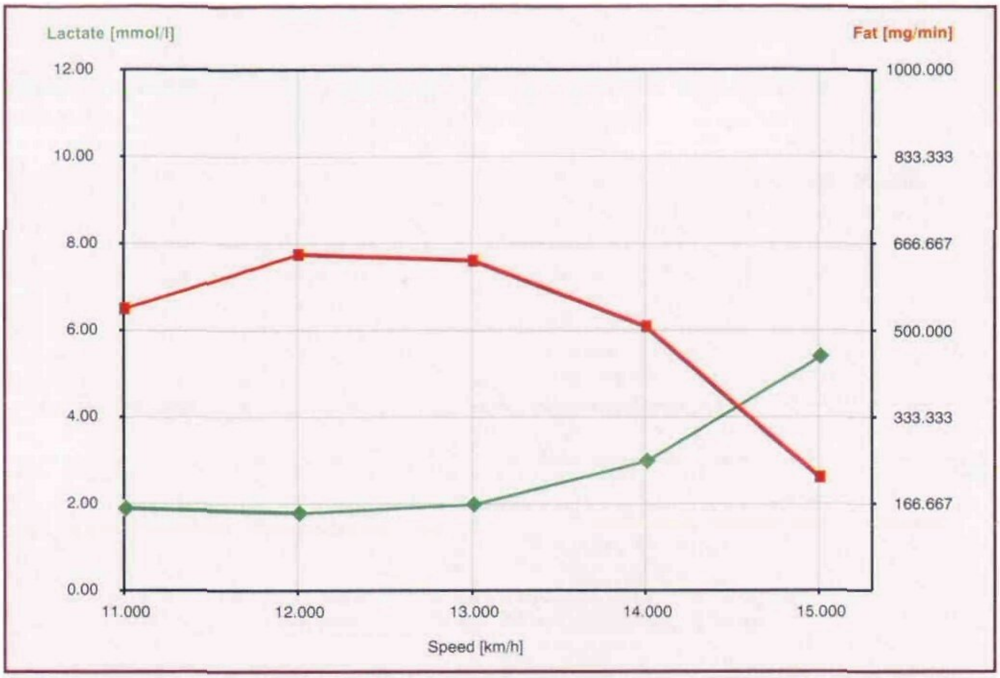


**Figure 6: Blood lactate concentration** (in millilitres per litre; black squares and continuous line) **and lipid consumption** (in milligrams per minute; black circles and dotted line) **as a function of walking speed ranging from 11 to 15km/h, recorded in a high level 50km race walker**

## REFERENCES


ARCELLI, E. (1976):

*Spesa energetica nelle varie prove di corsa piana. Atletica* leggera, Milano, no. 197, March, pp. 43-44

ARCELLI, E. (1994):

Che cosa mangiare e bere prima e durante la maratonina e la maratona. Atleticastudi, no. 5, pp. 397-401

ARCELLI, E.; LA TORRE, A. (1994A):

La gara dei 50 chilometri di marcia; spesa energetica e origine dell'energia. Atleticastudi, No. 4, pp. 215-218

ARCELLI, E.; LA TORRE, A. (1994B):

La carrera del los 50 kilometros del marcha. Boletin, Centro Regional IAAF Santa Fe, n. 11, pp. 18-21

ASTRAND, F.-O.; RODAHL, K. (1970):

Textbook of Work Physiology. McGraw-Hill Book Company, New York

COSTILL, D.L.; SALTIN, B.(1974):

Factors limiting gastric emptying during rest and exercise. J. Appl. Physiol., Vol. 37, pp. 679-683

COYLE, E.F. (1991):

Timing and method of increased carbohydrate intake to cope with heavy training, competition and recovery. J. Sports Sci., Vol. 9 (Special Issue), pp. 29-52

COYLE, E.F.; MONTAIN, S.J. (1992):

Benefit of fluid replacement with carbohydrate during exercise. Med. Sci. Sports Exerc., Vol. 24 (Suppl.9), pp. 8324-8330

DAVENPORT, H.W. (1982):

Physology of Digestive Tract. 5th edition, Yearbook Medical Publisher, Chicago

LAMB, D.L (1984):

Physiology of exercise., MacMillan Publishing Company, New York, 2nd edition, p. 57

MAUGHAN, R.J.; NOAKES, T.D. (1991):

Fluid replacement and exercise stress. A brief review of studies on fluid replacement and some guidelines for the athlete. Sports Medicine, Vol. 12, pp. 16-31

MORAN, T.H.; MCHUGH, P.R. (1991):

Distinction among three sugars in their effect on gastric emptying and satiety. Am. J. Physiol., Vol. 241, pp. R25-R30

NEWSHOLME, E.A. (1989):

Metabolic causes of fatigue in track events and in marathon. In: B. BENZI (ed.): Adavances in myochemistry, 2, John Libbey Eurotext Ltd., London, pp. 263-271

O'BRIAN, M.J.; VIGUIE, C.A.; MAZZEO, R.S.; BROOKS, G.A. (1989):

Carbohydrate dependence during marathon running. Med. Sci. Sports Exerc., Vol 25, no. 9, pp. 1009-1017