MARATHON RUNNING AND ADVERSE WEATHER CONDITIONS: A MISCELLANY

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ABSTRACT

This paper considers various predisposing and corrective factors for hypothermia and hyperthermia in marathon runners. It is concluded that a race should be cancelled or deferred if the forecast suggests that certain climatic thresholds are likely to be met or crossed.

HYPOTHERMIA

A marathon runner is very unlikely to die of hypothermia and there is no certain record of a death. Unlike a fell runner help and civilisation are never very far from a marathon runner. Hypothermia remains, however, an unpleasant and potentially dangerous complication. In the United Kingdom in 1983 at least four marathons were run out of season with the possibility of hypothermia from windchill conditions. Two recent races in particular illustrate the difficulties.

The 1982 Farnham marathon was run in rain with an ambient temperature of 12°C and a wind of 32 kph. Six runners were sent to hospital with hypothermia and an unknown number were helped by first aid workers. The early onset of darkness and the narrow country lanes made the retrieval of casualties difficult. The experience is still remembered with awe by local runners. The weather for the 1984 Guildford marathon was even worse. It was run on March 25th in a maximum ambient temperature of 7.6°C, a wind gusting to more than 48 kph and heavy rain in the second half. These conditions were accurately forecast by a meteorological office. Almost all the runners were inadequately clothed for the actual and predicted weather conditions and in conversation with some of them whilst awaiting the start it was evident that the risks were not appreciated. There were 416 runners who entered the second lap thus indicating their intention to run the full marathon. Of these 64 (15%) dropped out. Almost all the remaining 352 runners were very cold and wet and sought help at the finish. The St. John's Ambulance Brigade officials gave up registering names after the first 260. They dealt with the situation most effectively by herding the runners into eleven ambulances which had their heaters running at full and by hot drinks. Most recovered within a quarter to half an hour, but a few were retained for up to two hours. Two runners were taken to hospital but were not detained. Rectal temperatures were not taken. This marathon attracted hostile press criticism, which was a pity, as it is always very well organised.

The particular problems and hazards relating to out of season marathons are now beginning to emerge. It

should be a condition of entry to the race that runners will accept advice on the day about the wearing and carrying of additional clothing and care should be taken by the organisers that top clothing discarded at the start remains dry throughout a deluge. The runners should be passed at regular intervals by contraflow 'sweep-up' vehicles and there must be adequate means to rewarm large numbers at the end of the course. The race should start early enough to ensure that slow runners have finished before the light fades. As discussed later, in very severe conditions the organisers should be obliged to cancel the race.

Many factors predispose a runner to hypothermia. There are three, in particular to consider: the wind-speed, physique, and the use of non-steroidal anti-inflammatory drugs.

Wind velocity and windchill

A runner never runs in still air. The marathon runner's speed over the ground is 14-17 kph, which is equivalent to Force 3 on the Beaufort Scale ('leaves and small twigs are in constant motion'). The average speed of the 'breeze over body' depends on the shape of the course and the speed and relative direction of the wind. Even a Force 3 following wind has some effect, for no breeze ever blows at a constant speed from a constant quarter. On a linear course the 'breeze over body' rate will depend on the relative axis of the course and the axis of the wind. On a circular course the wind has little additional influence when Force 3 or less, but thereafter increasing wind strengths make the contribution of the runners' motion less and less relevant (Table I).

Windchill is the cooling power of wind and temperature on shaded dry human skin. The original index was developed by Siple (Falconer, 1968) and was based on experiments which determined the length of time required for water in a dry metal tube in winds of varying speeds to freeze. This index seems more appropriate for application to scantily clothed marathon runners than more sophisticated indices developed to apply to clothed persons (Steadman, 1971; Beal, 1974).

TABLE I

The relative contribution of the runner's speed (16 kph) and windspeed on a circular course to the 'breeze over body' rate.

Windspeed kph	Mean breeze over body kph	Difference kph
0	16	16
9	19	10
16	22	6
32	33	1

Falconer (1968) has published a normogram of Siple's indices and from it one may deduce, for example, that a temperature of 5°C and a windspeed of 55 kph (Force 7) is equivalent to a temperature in still air of -12°C. The mere motion of a runner through still air reduces an ambient temperature of 10°C to the equivalent of about 4°C. Thus the 'breeze over body' rate has a profound effect in predisposing a runner to hypothermia in cool conditions and preventing heat illness in hot conditions. No index exists which takes into account precipitation in addition to windchill factors, but wet conditions will greatly increase the risk of hypothermia.

Physique and hypothermia

Two runners of the same mass and a 30 cm (12 inches) height difference would have a difference in body area of about 15%. If the height difference is only 15 cm (6 inches) the area difference is still about 7%. Thus an ectomorphic runner has considerably more body area from which to lose heat compared with a shorter runner of similar weight.

The tall ectomorphic runner is further disadvantaged in two ways. Firstly, he will probably have less insulating subcutaneous fat than more balanced physiques. Secondly, lung size is correlated positively with height (Cotes, 1979) and the taller runner will probably lose more heat from the lungs by vaporisation and radiation than the shorter runner. In weather conditions predisposing to hypothermia first aid workers should be particularly wary of the slow, middle-aged, ectomorphic runner who becomes a casualty. The factors discussed above may operate to the runner's advantage in hot conditions.

Non-steroidal anti-inflammatory drugs

In one British marathon 10% of runners admitted taking a drug before the race (Porter, 1984) and one per cent took a non-steroidal anti-inflammatory drug (NSAI). The prostaglandins E₁ and E₂ may have a physiological role in the brain for temperature regulation (Holdcroft, 1980) and it is possible that their inhibition might predispose a runner to hypothermia. Ibuprofen, a NSAI drug, is now available without a prescription in the UK and its future frequent use by runners may be anticipated.

Oral or rectal temperatures

It is still possible to witness temperatures being taken by the oral route in the first aid tents at the end of marathons. When I ran for 15 minutes in an ambient temperature of 0°C then stopped and drank a cup of water, chilling of the mouth from air and water increased the difference between the oral and rectal temperature to more than 2°C compared with the usual 0.5°C. The oral temperature persisted at the low level of about 35.3°C for ten minutes before starting slowly to rise. At the end of 30 minutes it was still 1.3°C below the rectal temperature. After a hot cup of tea the oral temperature may rise to more than 38.3°C and remain high for more than 30 minutes. It is evident that it is important always to take the temperature by the rectal route.

HYPERTHERMIA

Important heat illness in marathon runners is rare. There are nine papers in the literature which quote figures from which the proportion of runners suffering from heat illness may be deduced and the mean percentage is 0.6 (range 0.1 to 1.4). These races were run with a mean wet bulb temperature of 22.2°C (range 12.6 to 28.6).

The definition of 'heat illness' presents a problem. It is quite possible for a runner with a normal rectal temperature to become exhausted and dehydrated on a cool day and no one would call it 'heat exhaustion'. But on a hot day this combination may attract the label, though the condition is no more than 'exhaustion in the heat'. The first label is diagnostic with prognostic implications, the second is merely descriptive. Only a raised rectal temperature will identify the runner with heat illness and at risk for immediate or delayed damage to parenchymatous organs.

There is a consensus of opinion that a rectal temperature of about 40°C is the threshold and core temperatures up to this limit are often normal findings in runners on a hot day (Costill et al, 1970; Kavanagh and Shephard, 1977; Wyndham, 1977). I have identified 26 cases where rectal temperatures were both taken and recorded and exceeded 40°C (Pugh et al, 1967; Sutton et al, 1972; O'Donnell, 1977; Hanson and Zimmerman, 1979; Hart et al, 1980; England et al, 1982) but there are only four case reports of subsequent renal failure (Dancaster et al, 1969; Nicholson and Somerville, 1978; Hart et al, 1980).

Many thousands of runners take part every year in marathon races and fun runs held in hot conditions, particularly in Canada, USA and Australia, and it is a remarkable testimony to the body's homeostatic mechanisms that there are so few recorded serious complications. There are probably four main reasons for this. Firstly, man evolved as a hunting creature in a hot climate and has developed appropriate adaptations.

Secondly, the clothing of runners is scanty. Thirdly, as already noted, a runner almost always has a cooling breeze blowing over his body, even when there is no wind. Fourthly, a steady pace permits efficient aerobic metabolism. Hanson and Zimmerman (1979) described four runners who collapsed with hyperthermia after increasing their pace; symptoms of heat illness occurred within five to ten minutes of the onset of increased effort. The additional energy demand might have been covered by an increase in aerobic metabolism, but it may have also been partly met by anaerobic metabolism. The net production per mole of glucose metabolised aerobically is 38 moles of ATP and when metabolised anaerobically it is only 3 moles of ATP (Ganong, 1981). The difference is partly accounted for by heat, thus anaerobic metabolism adds greatly to the production of waste heat (Wyndham, 1977). It is probable that the homeostatic mechanisms of the four runners were overwhelmed by the additional heat production coinciding with the inevitable dehydration. Runners entering for distance races in hot conditions need to be counselled, not only to drink freely, but also to resist the temptation to increase their pace towards the end of the race.

Good hydration

Good hydration helps protect a marathon runner, not only against heat illness, but also against soft tissue injury (Porter, 1984), and, more speculatively, against the possibility of the subsequent development of cataracts (Minassian et al, 1984). Few runners drink at every opportunity (Porter, 1984) and in 1983 three UK marathons had only five drink stations and one had only four (Williams, 1984). It is rare for fluid replacement to replace fluid loss, which may exceed two litres per hour (Costill et al, 1970). There is, however, one simple measure which might partly resolve this problem.

The usual plastic drink cup is about the size and shape of a yoghurt carton. If the runner is fortunate it is two-thirds full and contains about 100 ml of fluid. The modal number of drink stations at each British marathon in 1983 was eight (Williams, 1984). Thus if a runner at a typical marathon had conscientiously drunk 100 ml of fluid at every station without spillage, he would have only ingested 800 ml. A few would have drunk more, most would have drunk much less.

A taller cup would have three advantages. It is easily grasped by the runner, is relatively 'splash-proof' and when only half full contains 150 ml of water. At the same time it is stable enough not to be readily knocked over on the table. There is no guarantee that the additional fluid would be drunk, it might be splashed over the head, but at least the opportunity would be there.

CANCELLATION

When, if ever, should a marathon race be cancelled? In the context of UK marathons hypothermia is un-

pleasant rather than dangerous. There should seldom be grounds, therefore, for cancellation in the UK for cold conditions. The precise definition of wet windchill conditions, severe enough to be unacceptable, awaits a proper system of notification and a prospective study to correlate weather with casualty rates. It is possible that very occasionally a race held early in the season will coincide with conditions such as a wind force of 55 kph (Force 7) or more and an ambient temperature of 5°C or less. In dry conditions this would be equivalent to running in still air at a temperature of around -12°C or less. Rain would make the situation much worse. Even with an excellent organisation it would be difficult to justify starting a race in such weather. These conditions have not, however, occurred at all in February and March in the past ten years at London Airport and only on six occasions during these two months has a wind of above 57 kph been associated with an ambient temperature of 5°C or less. The risks then of extreme weather conditions on the day are small.

Hot conditions pose more of a danger to runners. The American College of Sports Medicine (1975) recommended that "distance races should *not* be conducted when the wet bulb temperature exceeds 28°C". The safe upper wet bulb temperature for sustained labour or marathon running is recorded elsewhere as about 25°C (Watt, 1967; Wyndham, 1977) and heat illness may occur at even lower wet bulb temperatures (Hanson and Zimmerman, 1979). The American recommendation is an extraordinary one. There is no record that a wet bulb temperature of 28°C has ever occurred in the UK; the highest in the past decade is 25°C and 22°C has only been reached at Heathrow Airport on three occasions during this period. Thus the American recommendation permits athletes to run in conditions so torrid that they have probably never occurred in the UK. Cancellation or deferment of a race should be mandatory if the wet bulb temperature is expected to reach 25°C.

It is difficult for any individual or group of officials to take responsibility for cancelling or deferring a marathon. Not only must they contend with the expectations of the runners and voluntary workers, but fiscal factors are also invariably involved. The race officials should be relieved of the responsibility for the decision. Most marathons are now run under AAA rules in the UK. Race organisers should be obliged to contact the meteorological office on the morning of the race. If the prediction is that defined weather thresholds will be met or crossed during the race then the rules should state that the race must be cancelled or deferred.

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References

- American College of Sports Medicine, 1975 "Position statement on prevention of heat injuries during distance running". *Med. Sci.Sports* 7: vii-ix.
- Beal, H. T., 1974 "An operational windchill index". *Atmosphere* 12: 18-30.
- Costill, D. L., Kammer, W. F. and Fisher, A., 1970 "Fluid ingestion during distance running". *Arch.Environ.Health* 21: 520-525.
- Cotes, J. E., 1979 "Lung function throughout life; determinants and reference values". Blackwell Scientific Papers, Oxford.
- Dancaster, C. P., Duckworth, W. C. and Roper, C. J., 1969 "Nephropathy in marathon runners". *S.Afr.Med.J.* 43: 758-760.
- England, A. C., Fraser, D. W., Hightower, A. W., Tirinnanzi, R., Greenberg, D. J., Powell, K. E., Slovis, C. M., Varsha, R. A., 1982 "Preventing severe heat injury in runners: suggestions from the 1979 Peachtree road race experience". *Ann.Int.Med.* 97: 196-201.
- Falconer, R., 1968 "Windchill, a useful wintertime weather variable". *Weatherwise* 21: 227-229.
- Ganong, W. F., 1981 "Review of medical physiology". Lang Medical Publications, Los Altos.
- Hanson, P. G. and Zimmerman, S. W., 1979 "Exertional heat stroke in novice runners". *J.Amer.Med.Ass.* 242: 154-157.
- Hart, L. E., Egier, B. P., Shimizu, A. G., Tandan, P. J., Sutton, J. R., 1980 "Exertional heat stroke: the runner's nemesis". *Canadian Medical Association J.* 122: 1144-1150.
- Holdcroft, A., 1980 "Body temperature control". Ballière-Tindall, London.
- Kavanagh, T. and Shephard, R. J., 1977 "On the choice of fluid for the hydration of middle-aged marathon runners". *Br.J. Sports Med.* 11: 26-35.
- Minassian, D. C., Mehra, V. and Jones, B. R., 1984 "Dehydrational crises from severe diarrhoea or heat stroke and risk of cataract". *Lancet* 1: 751-753.
- Nicholson, M. R. and Somerville, K. W., 1978 "Heat stroke in a 'run for fun' ". *Brit.Med.J.* 1: 1525.
- O'Donnell, T. F., 1977 "The haemodynamic and metabolic alterations associated with acute heat stress injury in marathon runners". *Ann.N.Y.Acad.Sci.* 301: 262-269.
- Porter, A. M. W., 1984 "How do marathon runners fare?" *Brit. J.Sports Med.* 18: 46.
- Pugh, L. G. C. E., Corbett, J. L. and Johnson, R. H., 1967 "Rectal temperature, weight losses and sweat rates in marathon running". *J.Appl.Physiol.* 23: 347-352.
- Steadman, R. G., 1971 "Indices of windchill of clothed persons". *J.Appl.Met.* 10: 674-683.
- Sutton, J., Coleman, M. J., Millar, A. P., Lazarus, L. and Russo, P., 1972 "The medical problems of mass participation in athletic competition". *Med.J.Australia* 2: 127-133.
- Watt, G. A., 1967 "An index of comfort for Bahrain". *Met. Magazine* 96: 321.
- Williams, B., 1984. Personal communication.
- Wyndham, C. H., 1977 "Heat stroke and hyperthermia in marathon runners". *Ann.N.Y.Acad.Sci.* 301: 128-138.

BOOK REVIEW

Title: PHYSIQUE OF FEMALE OLYMPIC FINALISTS
Authors: T. Khosla and V. C. McBroom
Publisher: Welsh National School of Medicine, Health Park, Cardiff
Price: £2.45 or \$5.00 in USA

This 70 page book lists the height, weight, age and other physical characteristics of 824 women finalists in the 1972 and 1976 Olympic Games.

Quantitative information on human structure, especially top-class performers, is all too rare, and any contributions of this nature are to be commended. On the other hand however, I feel that the authors, in the preface, make an unwarranted and rather naive attempt to "sell" the book on the grounds that it holds some sort of key to choosing one's ideal event. The norm in most physical activities is difficult to define, the ideal probably impossible, particularly when there are so many variables contributing to successful performance.

The data are of general interest and they may be of special interest to people involved in sport and/or research but they really do no more than spell out the already obvious to the coach and aspiring athlete. For example, if you are below average height you are unlikely to make a top basketball player; if you are small and skinny do not expect to take on Geoff Capes at shot; if you are big and fat do not look for success in marathons, and so on.

There are inherent dangers of misinterpretation when dealing with group data. Top-class sport is about individuals, and descriptive statistics such as mean and standard deviation, even when understood, are of little use to the performer or coach who is interested in personal performance of one athlete at one moment in time, not generalisations. On examining the 100 metres table in the text you can see height differences of 17 cms and weight differences of 20 kg among the finalists in 1972 and 1976. These ranges are so large that very few women of "average" height would be excluded.

Although it might appear that I would not recommend this text, this is not the case. It will obviously be of interest to sportswomen, coaches, trainers, equipment designers and research workers, but I am rather sceptical about some of the claims regarding the direct application of such data.

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