MARATHON TRAINING

For your personal best

A SPECIAL REPORT FROM

PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

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A CIP catalogue record for this book is available from the British Library.

Printed by: Baskerville Press Ltd
6-8 Newton Road, Salisbury, Wiltshire SP2 7QB

Published by Peak Performance Publishing

Peak Performance Publishing is a trading name of Electric Word plc
Registered office: 67-71 Goswell Road, London, EC1V 7EP
Tel: 0845 450 6404
Registered number: 3934419

ISBN: 1-905096-04-6

Publisher Jonathan A. Pye
Editor Isabel Walker
Designer Philip Morton

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From the editor

Marathon running, thought by many to be a flash in the pan during the fitness boom of the 1980s, is now more popular than ever, if record entries for the best-known races are anything to go by. Unlike track racing, which is dominated by elite competitive athletes, marathon running is truly democratic, attracting every category of participant, from fun runner to international racer, from charity fundraiser to club runner, from teenager to octogenarian.

This special report, prepared by the *Peak Performance* team of expert writers on training, conditioning, nutrition, injury and performance, is designed to appeal to people across that entire spectrum of ability and commitment. It carries advice-packed articles on muscle training (don't ignore your fast-twitch fibres), warm-ups (out with stretching, in with sport-specific drills), hydration (beat fluid loss with the aid of glycerol) and recovery (take a lead from our fictional hero Eric the endurance runner).

A self-confessed 'couch potato' describes his fascinating 10-year journey from 'average bloke' to international marathoner; a leading coach (and former European 5000m champion) laments the recent decline in endurance running standards; and the medical director of the world-renowned London Marathon gives the lowdown on marathon-related injury, illness and death.

But we kick off with a detailed tried and tested training schedule for the non-specialist prepared by the ultimate runners' guru Tim Noakes, whose massive tome *Lore of Running* is accorded near-biblical status by most serious athletes.

I hope you enjoy this special report and find it helpful in your preparation for this most gruelling yet rewarding of endurance events.

Isabel Walker
Editor

We present a comprehensive schedule for the non-specialist, tested in the lab and on the roads

If you are a novice and have completed all the training necessary to run a half-marathon, you should be ready to start training for a marathon, should you so wish. It is necessary to emphasise that if you started as a complete novice with no recent running experience, you should have undergone at least 25 weeks of training. If you start on the next phase of the programme without an adequate base, you will be at greater risk of injury once you start running more intensively with less rest between long runs.

The table overleaf details the programme that I suggest to ensure that the runner (who is training for 160 minutes per week and who has successfully completed at least a 10km race) will be able to complete a standard marathon in a further 26 weeks. The programme is a slight modification of the one we used successfully in 1983 to train 26 novices to complete a marathon within 36 weeks of their first 20-minute walk.

The key to the programme is the gentle extension in daily training volumes, with emphasis on the long runs, which increase by 10 minutes every second week.

This programme is clearly for those runners wishing to complete a marathon comfortably with a low risk of injury, and with the highest possible probability of success. It does not include speed or hill training which, if done properly, will undoubtedly improve your race time substantially.

Many programmes advise on the exact mileage that runners should cover when training for a marathon. This begs the

Tim Noakes' 26-week progression from a 10km race to a full marathon All figures are minutes

Day	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7	Wk 8	Wk 9
1	30	-	-	-	-	-	-	-	-
2	-	25	35	20	40	40	30	40	50
3	30	40	30	-	20	20	50	50	40
4	-	-	-	35	-	-	-	-	-
5	35	30	30	-	45	50	50	50	60
6	25	25	25	20	20	20	20	20	20
7	40	30	50	40	60	50	70	60	80
Day	**Wk 10**	**Wk 11**	**Wk 12**	**Wk 13**	**Wk 14**	**Wk 15**	**Wk 16**	**Wk 17**	**Wk 18**
1	-	-	-	-	-	-	-	-	-
2	30	60	65	60	70	70	70	70	85
3	55	35	40	30	40	30	40	35	40
4	30	60	30	50	60	60	70	70	75
5	55	40	40	35	40	35	30	35	40
6	-	-	-	-	-	-	-	-	-
7	70	90	80	100	90	110	100	120	110
Day	**Wk 19**	**Wk 20**	**Wk 21**	**Wk 22**	**Wk 23**	**Wk 24**	**Wk 25**	**Wk 26**	
1	-	-	-	40	40	-	40	40	
2	80	80	85	80	90	90	-	20	
3	45	40	35	40	40	40	40	10	
4	70	75	75	40	90	90	30	-	
5	40	25	20	35	40	40	-	-	
6	-	20	20	-	-	-	60	-	
7	130	120	140	130	150	60	20	Race	

question of what science tells us about the optimum training distances for marathon runners. In fact, there are few studies of the actual distances people run in training for a marathon. Thus, we do not really know what the optimum training distance is for the majority of novice marathon runners. The distances advocated in this programme have been arrived at empirically, but are compatible with the findings of a study by Grant and others[1].

When evaluating the training patterns of 88 runners in the

1982 Glasgow Marathon, Grant and colleagues found that the average distance run in training was 60k per week for the 12 weeks prior to the race, and this ranged from 24 to 103k. This study also debunked two important myths. Firstly, there is no relationship between weekly training distance and marathon time (as shown by Franklin and others)[2]. Secondly, despite their apparent inadequate training, the runners did not slow down dramatically after hitting their predicted 'collapse point' at about 27k. Thus, they could find no evidence to support the collapse-point theory proposed by Ken Young [3]. This theory holds that runners who do not train more than 101k per week 'collapse', and are reduced to a 'shuffle' when they race more than three times their average daily training distance for the last eight weeks before the marathon. Finally, as in the Franklin study [2], these novice marathoners were unable to predict their marathon times accurately. However, the accuracy of their predictions did improve the closer they were made to race day.

During my marathon running career, I achieved personal best times of 2:50:20 (42k/marathon), 3:59:49 (56k/35 miles) and 6:49:00 (90k/56 miles). I achieved these times on the training programmes described here. I present them as an option for those with a similar physiology and training capacity. A measure of my physiological capacity were my best times for certified courses of 60:59 for 16k/10 miles and 81:39 for 21k/half-marathon.

My personal training approach was similar to the legendary Arthur Newton's [4]. It included plenty of long, slow distance to the exclusion of speedwork. This was because I originally switched to running (from rowing) with the express intention of completing the 56-mile Comrades Marathon, regardless of finishing time. For the first 6-8 years of my running career, I trained exclusively by running long, slow distances. However, I now firmly believe that this training approach, which emphasises distance training to the virtual exclusion of speedwork, although very safe, is not the best way to train for any distance, including ultra-marathons. I endorse Roger Bannister's view that high-mileage distance training increases

Noakes' typical base training week
All figures in km (to convert to miles divide by 8 and multiply by 5)

	am	pm
Monday	5	7
Tuesday	7	7
Wednesday	7	7
Thursday	7	7
Friday	5	5
Saturday	24-32	-
Sunday	-	8-14
Total	**96-110**	

the athlete's speed of recovery from effort, but does not increase racing speed. The athlete must achieve a balance by doing just the right amount of speed training.

Thus, the evidence is that the fastest middle-distance and cross-country runners are the best at all distances, even the very long ultra-marathons. However, there is one important proviso – they need to have superior fatigue resistance. But this alone will not make a world-class marathon or ultra-marathon runner. For that, both speed and fatigue resistance are required.

With this background, I include details of the training practices I followed when running marathon races on a regular basis between the ages of 22 and 36. After that, I found that I could no longer train as hard as the programme required.

The initial goal of my hard training programme (see table above) was to condition myself to be able to run 110k per week, a distance that I have also found to be optimal for the majority of recreational runners who have major time constraints. This break-in phase lasted for 10-12 weeks, during which time my long weekend runs would not be less than 24k and not longer than 32k. The major indication that this phase had had its desired effect was that I started to finish the long runs so fresh that I wanted to run further on the following long run. At the same time, my average training speed increased and the hills that I ran became much easier. When this happened, I was ready to move on to the second phase of my programme, the so-called 'peaking phase'.

'If there is one contentious issue in training for distance running, it is the exact value of running many miles at low intensities'

If there is one contentious issue in training for distance running, it is the exact value of running many miles at low intensities. That the majority of runners spend most of their time training at quite low intensities has been shown by a number of studies. For example, a study of 13 elite New Zealand distance runners [5] found that their average training intensity was characterised by the following: their average heart rate was 145 beats-per-minute; their average percentage VO_2max was 64%; their average running speed 15.6k/9.75 miles per hour, which corresponds to 77% of the speed at which the lactate turnpoint occurred. Remarkably, only 4% of their training involved running at speeds greater than that at which the lactate turnpoint occurred.

Is low-intensity training unnecessary?

Another study found that the average training pace of a group of top German female marathoners corresponded to only 60% VO_2max, or less than 77% of the running speed at which their blood lactate concentrations reached 4 mmol.l-1.

However, I am not yet ready to conclude that all low-intensity training is unnecessary. Certainly, provided the total training volume is less than 100k/62miles per week, this low-intensity training would not seem detrimental. But its value for running performances, certainly over the shorter distances, has not yet been proven. I have also collated evidence showing how well many elite runners have performed on relatively little training [6]. The major benefits of heavy training volumes in excess of 120k/75miles per week are to increase the strength of the connective tissue in the muscles and the resistance to the eccentric muscle damage that produces fatigue after running 30 or more kilometres (19 miles), which then increases your ability to keep running beyond the marathon ‘wall’.

The aim of peaking is to increase the training load further, by adding speed training sessions, either in the form of intervals, speed-play (Fartlek), time-trials or short-distance races (5-16k/3-10 miles) for a period of 4-6 weeks before competitions. This form of training produces dramatic changes in racing speed, but if maintained for too long it can induce early symptoms of overtraining. Thus, it is a high-risk/high-reward period of your training.

The next phase of my hard training cycle differed, depending on the length of the race for which I was preparing. For shorter distances, I emphasised mostly speed training and maintained the weekly training distance at about 120k/75 miles per week. For ultra-marathons, I emphasised distance training and long weekend runs, only adding speed training when I had completed the heavy distance training.

During the peaking phase of my standard marathon training, I would emphasise speed training sessions either on a Tuesday or a Thursday, and would run two or three races of 10-16k (6-10 miles) – but no further. I found that these are the optimum racing distances for preparing for both the 10k race and the marathon. Longer races tend to cause more severe muscle damage from which recovery is slow. Also, from a psychological viewpoint, the marathon breaks up neatly into two 16k/10 mile races and one 10k/6 mile race. Thus, during the marathon race, I would concentrate on running as close to my best times for each of these distances as was possible. When properly prepared, it is remarkable how close you can come to this goal.

During the penultimate week before the marathon, I would reduce my training to 50-80k/30-50 miles of easy running, and would rest and carbohydrate-load for the last three days before the race. During the intervening four days, I would incorporate three days of mild carbohydrate-restriction and runs of 12-18k/7.5-11 miles, depending on how I felt.

The ideal taper for marathon and ultra-marathon runners has not yet been established in a scientific trial. My bias is to believe that there should be more rest and less running during the tapering phase, and certainly more days in which you do no training at all.

I have written elsewhere about the 'Zatopek phenomenon'(7) in which elite athletes achieved remarkable performances after a period of reduced training – in the case of Zatopek, even after being hospitalised for two days before his record-breaking performances. Some 30 years since this phenomenon was first recognised, I realise that I ran one of my best 56k/35 mile ultra-marathon races after a period of enforced rest. I ran the race a mere three weeks after undergoing surgery to my foot, which prevented me from running for two weeks. In the last week before the race, I had only been able to fit in a few jogs.

Without trying, I ran a time that was less than 40 seconds slower than my best, over the distance achieved three years later after a much more intensive training programme, but for which I did not taper properly. The last word on the ideal taper has yet to be written.

Tim Noakes

Adapted from The Lore of Running (fourth edition) OUP 2001

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How one former couch potato found a talent and then called on the appliance of science to become an elite performer

This is a personal account of my life as a runner. At the age of 30 I was just an average bloke. I was stuck in a rut with a stressful job that had long, unsociable hours. I was overweight, taking no exercise and enjoying a smoke and a drink. Then something happened: whatever it was – an early mid-life crisis or a sudden awakening of an inner competitive spirit – it eventually changed me into an international athlete. It is an unlikely tale but this is exactly what happened.

Not all of this story may seem relevant, but I believe it highlights a number of factors which athletes of all standards should consider in their pursuit of peak, or at least improved, performance. It shows why there is a need for careful planning, patience and progression in your lifestyle, training and racing. How vital the relationship is with your coach. How both athlete and coach have to have total belief in what they are doing and total respect for each other. Each has to have a full understanding of, and commitment to, the plan. Your coach has to understand you as a person. Yes, there are coaches who can motivate and inspire groups of athletes, but to really coach an athlete takes time, energy, commitment and knowledge. I hope this article also demonstrates the need for the athlete to have personal responsibility for, and understanding of, their own training. After all it is the runner who does the running so, to my way of thinking, there had better be some good reasons why

I am doing it! An athlete and a good coach should also be open-minded enough to evaluate and experiment with new and different training methods.

This journey would never have happened were it not for the support of my wife or the guidance, generosity and knowledge of physiologist and coach Dr Tony Trowbridge. I must also thank Bruce Tulloh and his wife, and a group of world-class Kenyan athletes, who allowed an unknown old guy to be part of their group and share in their training methods for two months.

It was a journey that would last just over 10 years. Along the way there were many unforgettable and exciting moments. There was also a great deal of hard work and disappointment. It was, without question, a journey that changed me as a person.

‘I had no concept of pace or recovery. I had no plan and no patience. Eventually this would lead to frustration and disappointment and in that unpleasant combination lay real potential for failure’

The first few steps of any running career need encouragement and motivation. I was lucky enough to start my journey on the trails and fells of Ambleside in the Lake District. Not only was the scenery inspirational, but there was also a very friendly, small running club, Ambleside AC, that helped me get out and run. My running at that time was based on enthusiasm. It was simple: I just put my shoes on and ran. I had no knowledge about what I was trying to do. I had no idea of the changes my body would have to go through to become a runner. I had no concept of pace or recovery. I had no plan and no patience. Eventually this would lead to frustration and disappointment, and in that unpleasant combination lay real potential for failure; it is a combination that has claimed many athletes – even good ones – in the past.

I was trying to run with people who were much better runners than me. I was running at their pace, often over difficult terrain. Yes, I was losing weight: I had weighed in at 190lbs and 22% body fat, and I was getting fitter but I was breaking down on a regular basis. Why? At that time I had no idea. When I was on an ‘up’ part of the cycle, races and results were pretty good; I was finishing in the top 10 of medium-length fell races and I had run 31:05 for my first 10k on the road. For most people in their first year of running that would have been enough. But I was hungry for more. The problem was the downside: this left me feeling totally fatigued and despondent and wanting to give up running before I had even started. I went through a number of cycles like this before deciding that there had to be a better way.

I had started to read running magazines and became interested in articles on physiology and heart rate. I decided the control that these concepts offered must be of some help in my situation. I bought a heart rate monitor and was ridiculed by many fell runners for doing so, but decided I needed someone qualified to show me how to use it. I made several enquiries with various institutions and eventually had a meeting with Dr Tony Trowbridge, who was in charge of the Medical Science department at the University of Sheffield. This was to be a major step in my athletic career.

My life was about to change

I was fully assessed by Tony and his team. There were machines, leads and tubes everywhere. I ran to exhaustion and they tested everything: VO_2max, running style and gait, running economy, heart rate, blood lactate, flexibility, strength, body composition, diet, work and even sleep patterns. My life was about to change. The bar was about to be raised and I was about to train, and be looked after, like a professional athlete.

We discussed and planned our short-, medium- and long-term objectives. We discussed and planned my training routine. The discussion, questioning and understanding of the science underpinning each training session gave clarity to what we were trying to achieve.

It was important I understood why. Tony was not only at the top of his profession in human performance but he was a runner himself and devoted a great deal of time to thinking through and considering his coaching. Not only did he fully understand me as a person but he was also a coach, who understood what it was like to do various sessions and could also explain to me why we were doing them.

My approach to running changed immediately, and so did the size of my telephone bill. Training became a science. Other athletes thought I had lost the plot and enjoyed a joke at my expense. But I guess that's the price for being different. The important thing was I believed in the plan and I knew it would make me a better runner.

'Each time I ran I knew exactly why I was running, I knew what was the correct intensity and duration and what that run was going to achieve'

Whereas before I had just run how I felt, now I knew every step was meant and controlled. I ran everything to a prescribed percentage of maximum heart rate. Each time I ran I knew exactly why I was running, I knew what was the correct intensity and duration and what that run was going to achieve. Because I was training to a plan, I was able to enjoy my easy runs and days off without feeling guilty. Because I was refreshed, I was able to work hard and successfully complete a threshold, hill or interval session. I started to understand what I was doing. During harder sessions we also took blood samples that were analysed for lactate levels. It wasn't always easy to get a few drops of blood out of a cold finger into a tiny phial on top of a Lakeland hill in the middle of November. However, it was important as the blood lactate level, along with the heart rate readings, gave us accurate feedback about my performance and the intensity during the session. For the first time I understood why rest and recovery were to be counted as an important part of my training routine.

Meanwhile, analysis of my body composition showed I was carrying too much body fat. For me, my diet was always going to be the toughest part of my regime. I have a sweet tooth, which has never helped my cause. Trying to lose body fat percentage as I trained through a northern British winter was as tough as it gets for me! I know deep down it was probably one of the areas where I could have been more dedicated. I managed to get to a race weight of 143lbs, which was good, but when I could lose those extra few pounds and race at 140lbs, I was flying.

When I had my diet analysed, it was clear I was placing too much emphasis on carbohydrate. 'So what's wrong with that?' I hear you say. A good runner's diet! The problem was that I had been eating very little quality protein for growth and repair. The analysis also showed that the overall quality of my diet was poor. The problems didn't stop there: I was also in a state of constant dehydration because I was not drinking enough fluid. These were some of the reasons I had been feeling so fatigued and breaking down. Failing to eat a nutritionally balanced diet, with the necessary variety of minerals, or drink the right amount of fluid on a regular basis sounds like an elementary mistake. I have found from other runners, however, that it is an area where a lot of up-and-coming athletes have problems. It is an area that has such a fundamental effect on performance that it requires as much focus and planning as the physical training.

Treadmill training worked for me

Another element that changed in my routine was the use of a treadmill in my training. This again set me up for more ridicule. But it worked for me. I was living in the heart of the Yorkshire Dales, which was great for good trails and quiet roads. However, the weather was often poor, with strong winds. The nearest track was an hour away, and very exposed. We decided that having a controlled environment for my speed sessions was important. I had a treadmill installed in my garage. It was to prove a very useful tool and one that I would learn to use to good effect.

Fell running had been a good grounding: it had given me good leg strength, strong ankles and knees, good balance and really good leg speed from long, fast descents. Treadmill running enhanced that leg speed. We found that I could run quality sessions in a controlled environment. We could make incremental changes in speed, gradient or recovery depending on my performance. We could also collect the heart rate and blood lactate information. Running on the treadmill gave me the opportunity to practise mental focus for races. It also allowed me to think about style and relaxation, concentrate on my running rhythm and pace judgement. I could do all this in the relative comfort of my garage. There were no climatic influences and I could wear racing kit instead of layers of protective clothes battling into a gale. Some may say that the latter is character-building! They may have a point but I felt I got enough character-building in my races.

My training also included good sessions of threshold and hill work. All this was done to a planned heart rate and recovery. I learned that my training now required a different mental approach: I had to be patient and initially slower doing the sessions governed by heart rate, and that meant accepting whatever time or distance I got on the day.

Working in this carefully planned, patient and progressive routine, my body and performances responded. My body was able to accept the small changes without rejection or illness. Times and race results both improved. I was now able to plan race tactics based on my strengths. I learned that no matter how competitive I wanted to be mentally in a race, sometimes I had to be patient physiologically. If the pace were too fast at the start of a race, I would produce a better performance by backing off a little and working my way through the field.

The early pace was vicious

A good example was my first English National Cross-Country Championships. The start of the 'National' is traditionally a fast charge. The year I ran in South Shields, most of the course was dry and the early pace was vicious. I dropped off the pace because I knew that if I had gone with the pack my blood lactate levels would have been through the roof and it would have taken most of the race to recover. I knew this from training and had a good feel as to how hard I could push my body and yet keep lactate levels manageable. After the first half lap I was about 35th but I was in control. I then kept mentally strong and maintained a good, even pace while others around me suffered from the over-exuberant start. I eventually worked through to fourth, missing a bronze medal by just two seconds.

My results became more consistent and I was always in the shakedown at the quality road and cross-country races. We tried to ensure that I did not over-race. Tony was always very wary of returning to what he called 'the valley of fatigue' and always tried to freshen me up after a period of hard work. It worked as I went from running 31 minutes for 10k, and 50 minutes for 10 miles, to 29.04 for 10k, and 48.15 for 10 miles. Tony was reluctant to let me run many longer distances, being wary from his personal bad experiences of just how much races like the marathon can take out of you. He was also concerned about me picking up long-term injuries. For that reason I never pushed him to let me try a marathon even though deep down I considered it the ultimate running challenge.

Dr Tony Trowbridge died aged 52. Ironically, he suffered a massive heart attack. I was in Portugal, warm-weather training. It was the saddest day of my life. He had been much more to me than a coach.

I have found that running has many more benefits than just physical fitness. My running helped me through this difficult time. I was fortunate in that Tony had fully involved me in the training process. If I hadn't been so involved, then the story may well have ended right there. But it didn't and it would have been wrong if it had.

However, it was never going to be quite the same. Tony was the control factor; he always erred on the side of caution. I guess this was because he was a scientist and felt responsible for me as the runner. It was perhaps inevitable that I lost some of this control factor and definitely did get a few things not quite right from then on.

I decided to try altitude training and went with a group led by Bruce Tulloh, including Richard Nerurkar (then the top British marathoner), to Font-Romeu in the French Pyrenees. I am not sure altitude training necessarily improved my performance, but what did work for me was the training camp life. It would drive some people nuts, but a simple life of training, eating and sleeping, with no distractions, was no problem for me. But there was a different problem: I was training too hard. Furthermore, I was not training for myself, but as part of a group. I was doing big mileage and hard sessions, but there was not enough rest or recovery! I was basically in great shape and, although I could get away with it in the short term, it would eventually take its toll.

But I was still running well and about to turn 40, so I decided to try to earn some money on the American masters (veterans or over-forties) road race circuit. With a young family and a mortgage it was always a juggling act to balance the books. Running for money is not what I would recommend, as it did affect my performance, but that is how I made my living. My sponsorship with Adidas also helped to support me as a full-time athlete.

I went to the US just after my 40th birthday in August 1997 and based myself outside Boston. There was a series of five good money races in a six-week period. I would train during the week and then fly to a race over the weekend. But my first big race on US soil was not good. I had gone from training very well 10 days previously to really struggling. Yes, there was jet lag and the heat and humidity, which you have to experience to really appreciate. But I was just exhausted. I had fallen into the valley of fatigue. I did win my age category and capture the all-important prize money – but only just. I was hanging on.

‘I had never done a marathon for the reasons I have explained, but decided that I would give it a go. I was making my marathon debut at the age of 40!’

After that, I rested more and results improved dramatically. Not only did I win my category but I was usually finishing as the first non-Kenyan in 9th or 10th place overall and running close to world masters (over-40) records. However, the cumulative effect of training, travel, racing and still too little recovery was starting to catch up on me.

I had decided that I would race again in America in the spring, as there was another series of good money races, culminating in the Boston Marathon. I had never done a marathon for the reasons I have explained, but decided that I would give it a go. I was making my marathon debut at the age of 40!

I set up a trip to Kenya and had a wonderful experience. All in all, I spent two months in Kenya, most of it in Nyaruru. It was a very simple and humble existence, but I had everything I needed. Great running trails, wonderful home-grown food and lots of rest and relaxation. I wanted to learn how to become a marathon runner. I ran with a group of 40 Kenyans every morning at 6am. There were many world and Olympic champions among them. They made me welcome and I like to think I earned their respect for the effort I put into my training with them. The great steeplechaser Moses Kiptanui was the boss. Even as a 3,000m runner he ran 21k each morning in November! I learned the value of threshold running and the emphasis the Kenyans put on hill running.

Africans listen to their bodies

We tend to assume that the Africans are haphazard in their training methods. From my experience I have to disagree. They work very hard, running hills from November until April. They run some great threshold sessions. They never ignore speed. But they have made rest and recovery into an art form. They listen to their bodies exceptionally well. They also get a one-hour massage, of the most comprehensive type I have ever had, every day!

I returned to the US for what was to be the last time as an athlete. I based myself in Boulder, Colorado, and stayed with top American marathon runner Mark Coogan and his family. I trained and raced as before to earn money, and the result was I ran a tired marathon in Boston. Still, I recorded 2:17:08 for a marathon debut, which was not bad for a veteran virgin. I think I was capable of a lot better but, after an excruciating wait and against all the odds, the selectors picked me to run the marathon for England in the Commonwealth Games in Kuala Lumpur.

For that race in KL I sacrificed everything. I did everything I could to run my best: I didn't race too much; I trained at altitude and then acclimatised to hot and humid conditions; I planned my marathon race considering my fitness and the conditions. I felt under some pressure believing, rightly or wrongly, that I was running for all the 40-year-olds who might ever have a chance of running in a major Games. I desperately did not want to let anyone down. I feel my plan worked. The acclimatisation, my fitness, mental strength, pace judgement, patience and hydration plan all came together. In a field of much faster runners, I finished 10th at my first and only international Games.

For me that was it. It could not get any better than that. I had reached a level that 10 years earlier would have been unimaginable. I felt there was nothing left to give and I retired from serious running a couple of months later.

Looking back would I do it all again? Too right I would. But would I change anything?

With the aid of hindsight, I think I would. Science would always provide the fundamental building blocks of the whole training regime. Without it there was no plan, no measured starting point and no measured improvement. However, I think the training at times was perhaps a little too cautious because of our interpretation of the science. Perhaps I would run the same mileage but include more threshold work and definitely more Kenyan-style hill work during the winter months. If I had a choice I would have raced less for money, but in the absence of handouts I didn't have that luxury. Finally I would have put that little extra bit of effort in on my diet.

Keith Anderson

Why marathoners and other endurance athletes cannot afford to ignore the vital contribution of fast-twitch muscle fibres

You would normally think of maximising fast-twitch muscle fibre potential to enhance speed and power. But this article focuses on getting the most out of those same fibres for endurance activity.

Biopsies are used to determine what types of fibres exist within our muscles. A special needle is pushed into the muscle and a grain-of-rice-size piece of tissue extracted and chemically analysed. Two basic fibre types have been identified via this process: slow-twitch (also known as type I or 'red' fibres) and fast-twitch (aka type II or 'white' fibres). Type II fibres, as we shall see, can be further sub-divided into type IIa and type IIb variants.

Slow-twitch muscle fibre contracts at almost half the speed of fast-twitch fibre – at 10-30 twitches per second compared with 30-70 for the latter. Slow-twitch fibre has a good level of blood supply, which greatly assists its ability to generate aerobic energy by allowing plentiful supplies of oxygen to reach the working muscles and numerous mitochondria.

Mitochondria are cellular power plants; they function to turn food (primarily carbohydrates) into the energy required for muscular action, specifically adenosine triphosphate (ATP). ATP is found in all cells and is the body's universal energy donor. It is produced through aerobic and anaerobic energy metabolism and, consequently, through the associated actions of both slow- and fast-twitch muscle fibre.

Slow-twitch fibre is much less likely than its fast-twitch counterpart to increase muscle size (hypertrophy), although well-trained endurance athletes have slow-twitch fibres that are slightly enlarged by comparison with sedentary people. The most notable training effects, however, occur below the surface.

Subject to relevant endurance training, these unseen changes include:

- An improved aerobic capacity caused by fibre adaptation. Specifically this involves an increase in the size of mitochondria, boosting the ability of the fibres to generate aerobic energy;
- An increase in capillary density, which enhances the fibres' capacity to transport oxygen, and thus to create energy;
- An increase in the number of enzymes relevant to the Krebs cycle – a chemical process within muscles that permits the regeneration of ATP under aerobic conditions. The enzymes involved in this process may actually increase by a factor of two to three after a sustained period of endurance training.

Blood lactate plays a crucial role in energy creation which is not, as many people mistakenly assume, restricted to the latter stages of intense exercise.

Lactate is actually involved in energy production in our muscles at all times, although response to lactate generation varies according to fibre type. A brief consideration of this process will begin to explain why the relationship between fast- and slow-twitch fibre is crucial to optimum endurance.

Fast-twitch fibres produce the enzyme lactate dehydrogenase (LDH), which converts pyruvic acid (PA) into lactic acid (LA). The LDH in slow-twitch muscle fibre, however, favours the conversion of LA to PA. This means that the LA produced by the fast-twitch muscle fibres can be oxidised by the slow-twitch fibres in the same muscle to produce continuous muscular contractions.

When LA production reaches a level where it cannot be recycled to generate steady-state aerobic energy, endurance exercise moves into anaerobic territory – with less reliance on oxygen and more on stored phosphates for energy production.

There will come a point, under these conditions, when an athlete reaches his or her 'lactate threshold', at which point further exercise becomes increasingly difficult and the athlete is forced to slow down and ultimately stop.

As we shall see later, this 'anaerobiosis' and its exercise-halting effect may be as much a consequence of brain activity as of muscular limitations, especially under extreme endurance conditions.

'Failure to train fast-twitch fibre to contribute to endurance performance will result in lactate threshold being reached – and performance arrested – at a much earlier point'

Well-trained muscles 'drink' lactate

Well-trained endurance athletes are able to generate blood lactate levels that are 20-30% higher than those of untrained individuals under similar conditions. This makes for significantly enhanced endurance as their muscles no longer drown in lactate but rather 'drink' it to fuel further muscular energy. To continue the analogy, the untrained individual's muscles would get 'drunk' on lactate after just a few intervals – or perhaps that should be rounds!

As noted, failure to train fast-twitch fibre to contribute to endurance performance will result in lactate threshold being reached – and performance arrested – at a much earlier point. Unlike the 100m sprinter, who can ignore his slow-twitch fibres altogether in training without damaging performance, the endurance athlete has to train all fibre types in order to maximise sustained muscular energy.

Most people are born with a relatively even distribution of fast and slow-twitch fibres, suggesting that power and endurance athletes are 'made' rather than born. As exercise physiologists McKardle, Katch and Katch point out, 'studies with both humans and animals suggest a change in the biochemical-physiological properties of muscle fibres with a progressive transformation in fibre type with specific and chronic training'(1).

Table 1, overleaf, shows the extent to which fibre type can be 'altered' after training for selected endurance activities, although whether these changes are lasting is open to debate, as we shall see.

We have shown how slow-twitch fibre adapts to endurance training. Now let's take a look at how fast-twitch fibres respond.

- Type IIa or 'intermediate' fibres can, in elite endurance athletes, become as effective at producing aerobic energy as slow-twitch fibres found in non-trained subjects. Like slow-twitch fibres, these fibres (and their type IIb counterparts) will benefit from an increase in capillary density. In fact, it has been estimated that endurance training that recruits fast- and slow-twitch muscle fibre can boost intramuscular blood flow by 50-200% (2);
- Type IIb fibres can play a much more significant role in sustained energy release than had been assumed, according to research carried out by Essen-Gustavsson and associates (3). These researchers studied muscular enzyme changes brought about by endurance training and concluded that type IIb fibres were as important to endurance athletes in terms of their oxidative energy production and the clearance of exercise-inhibiting phosphates as type IIa fibres.

A raft of relatively recent research indicates that intense training efforts – eg three-minute intervals at 90-95% of max heart rate/over 85% of VO_2max, with three-minute recoveries – are great ways to boost lactate threshold (as well as VO_2max, economy and strength). These 'lactate-stacker' sessions, by their very nature, rely on fast-twitch fibre to generate power. Note, though, that these workouts are very tough and stressful

Table 1: Percentage slow-twitch fibre in male deltoid (shoulder) muscle

Endurance athlete	% slow-twitch fibre in deltoid muscle
Canoeist	71%
Swimmer	67%
Triathlete	60%

Adapted from McKardle et al (5)

and should be used judiciously.

Endurance gains can be made much more quickly through capillary adaptation in fast- and slow-twitch fibre with anaerobic training methods, such as the lactate stacker workouts, than with less intense aerobic training.

Although it is possible to train fast-twitch fibre to take on more of the slow-twitch blueprint, taken to extremes – especially through the use of slow-twitch steady state training – this may not actually be the best strategy for endurance athletes.

The marathon runner Alberto Salazar once said that he aimed to train aerobically hard enough to lose his ability to jump [(4)]. In other words, he was trying to convert all his fast-twitch fibres into slow-twitch ones in terms of their energy-producing potential so that they could contribute all their energy to his marathon running.

The need for a sprint finish

However, for a variety of reasons, losing all fast-twitch speed and power ability may not actually be a good idea. For example, at the end of a closely-fought marathon there may be a need for a sprint, requiring fast-twitch fibre input.

Even more specifically, there is the anaerobic/aerobic component of an endurance activity to consider, and the speed required to complete it competitively. An 800m race or a 2k row calls for an anaerobic energy contribution of around 40%, and athletes in these disciplines must be fast and powerful to succeed.

Fast-twitch fibres have to be trained accordingly; it's no good turning them into plodders with an emphasis on slow-twitch, steady state work, if they are needed to produce a short or sustained kick and a sizeable energy contribution.

The recent research into lactate stacker sessions and the vital role of lactate threshold as the key endurance performance variable further substantiates the need for the development of a high-powered endurance contribution from fast-twitch fibres.

Despite virtually undisputed evidence that all muscle fibre types will adapt to a relevant training stimulus, it is less certain

'Recently, research has begun to appear on the so-called 'central governor', which is seen to be the determinant of the body's ability to sustain endurance activity by tolerating increasing intensities of exercise'

whether these changes are permanent. One of the few studies concerned with the long-term effects of endurance training was conducted by Thayer *et al*, who looked at muscle-fibre adaptation over a decade [6]. Specifically, they compared skeletal muscle from the vastus lateralis (front thigh) in seven subjects who had participated in 10 years or more of high-intensity aerobic training with that of six untrained controls.

They found that the trained group had 70.9% of slow-twitch fibres compared with just 37.7% in the controls. Conversely, the trained group had just 25.3% fast-twitch fibre, compared with 51.8% in the controls. The researchers concluded that endurance training may promote a transition from fast- to slow-twitch fibres, and that this occurs at the expense of the fast-twitch fibre population.

However, it seems that slow-twitch (and fast-twitch) muscle fibre tends to revert back to its pre-training status after a period of inactivity (although aging may provide an exception to this rule, as we shall see later). In fact, the theory is that muscle fibre has a fast-twitch default setting. This is entirely logical: since we use our slow-twitch fibres much more than our fast-twitch ones on a daily basis, a period of inactivity would de-train slow-twitch fibre and allow fast-twitch fibre to regenerate and convert back to a faster contraction speed. The interesting and slightly less logical aspect of this process is that it does not necessarily require speed training, as demonstrated by research on muscle tissue rendered inactive by accident or illness [7].

When it comes to recruiting winning muscle, it is impossible to overlook the vital role of the brain. Muscle fibre can only function at the behest of our brains, and it is possible that athletes 'learn' how to tolerate the pain associated with lactate build-up, for example, and consequently become better able to recruit their muscle fibres.

Recently, research has begun to appear on the so-called 'central governor', which is seen to be the determinant of the body's ability to sustain endurance activity by tolerating increasing intensities of exercise. It has been argued that the governor's setting can be altered through the experience of intense exercise and a corresponding shift in willpower to permit greater endurance perseverance. This theory has been substantiated by evidence that muscles can still hold onto 80-90% of ATP and some glycogen after intense endurance efforts – *ie* when the athlete has 'decided' to stop exercising.

It has been suggested that the body – and, for our purposes, its muscles – will always hold onto some crucial energy-producing materials, just in case it is called upon to react in an emergency. This is seen as a legacy of the unpredictable life that confronted our prehistoric ancestors, who never knew if they would need a bit more energy to flee from a sabre-toothed tiger after a long day's hunting and gathering!

When the brain shuts down the body

Closely related to the thoughts on the 'governor' is the 'central (nervous system) fatigue hypothesis', postulating that the brain will 'shut down' the body under certain conditions when there is a perceived threat of damage to vital organs, irrespective of an individual's fitness. The conditions specifically identified to trigger central fatigue are high altitude and high temperatures, although researchers believe it could also swing into play under less taxing conditions.

The famous exercise physiologist and runner Tim Noakes states: 'There is no evidence that exhaustion under these conditions is associated with either skeletal muscle "anaerobiosis" or energy depletion.... There is sufficient evidence to suggest that a reduced central nervous system recruitment of the active muscles terminates maximum exercise'(8).

Various methods have been used to try to trick the brain into keeping muscle fibre recruitment going under extreme conditions. With regard to high temperatures, these involve 'pre-cooling' strategies, such as ice baths or ice helmets. These and similar strategies are designed, quite literally, to cool the brain and extend the body's 'heat stop switch' threshold.

As mentioned previously, aging also has an influence on the development of endurance muscle fibre, with fast-twitch fibre declining much more rapidly than its slow-twitch counterpart – by as much as 30% between the ages of 20 and 80.

By contrast, endurance athletes can expect to maintain their slow-twitch fibres and even increase them by as much as 20% over a sustained training career. The trouble is, though, that without fast-twitch fibres endurance performance will inevitably decline.

In summary, then, developing your endurance capacity relies on a number of adaptations, as follows:

- Enhancing the already high oxidative capacities of slow-twitch fibres;
- Improving the capacity of fast-twitch fibres to contribute to endurance activity, taking account of distance and the need for both sustained and 'kicking' power. This process may, in fact, hold the physiological key to optimising endurance performance;
- Working on mental strategies to develop increased endurance tolerance and the sustainable contractile properties of all muscle fibre types;
- Using pre-cooling techniques to delay physiological shut-down.

John Shepherd

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A new-style dynamic, sport-specific routine for runners

It is a common human failing to look very hard – maybe too hard – at something and still fail to see what's staring you in the face. This may explain why coaches and athletes have continued to keep faith with the old-style warm-up despite mounting evidence that it doesn't do what it says on the tin.

It's a given that we need to warm up before we sprint, hit a tennis ball or attempt a clean and jerk. The process prepares us mentally and physically for the task ahead. Traditionally, athletes from most sports have been used to raising their body temperature with 5-15 minutes of gentle cardiovascular (CV) work and then stretching off. As a long jump athlete, I can remember jogging a couple of laps to get really warm, then sitting and chatting for the next half an hour while supposedly stretching. By the time the session started, I'd often be cold both physically and mentally. My body would have switched off and I would be far from optimally prepared for the dynamic activity to follow; in fact I would literally have to warm up all over again.

'The 'new' theory about warm-ups is that we should replace the old generalist approach with a much more dynamic, focused routine, specifically tailored to our chosen sport'

Stretching was a major component of the 'old' warm-up, with coaches constantly reminding me that my range of movement had to be improved. But, with hindsight, the impact on my long jump performance of being able to do the box splits or clutch one hand to the other behind my back seems negligible.

The 'new' theory about warm-ups is that we should replace the old generalist approach with a much more dynamic, focused routine, specifically tailored to our chosen sport. The various drills we employ need to warm up our muscles specifically for the movements that will be required of them in the activity to follow. In this way specific neuromuscular patterning will be switched on and specific, functional range of movement developed.

It seems obvious, yet for some this is an almost revelatory concept. Many coaches will have to turn their old ideas on their heads. Athletes, too, will need convincing to throw out the old concepts about warm-ups and usher in the new.

But, in fact, the dynamic, focused warm-up is not as new a concept as it appears. Athletes from the former Soviet Bloc were using these types of warm-ups as far back as the 1970s – decades before they came to mainstream attention in the West. I remember attending a training course with former long jump world record-holder and (at the time) head Soviet coach Igor Ter-Ovanesian in the early 80s, and being put through a short, sharp warm-up, comprising star-jumps and various agility moves. On receiving the instruction to warm up, all athletes attending the course had begun by plodding round the track, only to be called back by an exasperated Ter-Ovanesian and instructed in the 'new way'. Yet so entrenched were our ideas – and those of our coaches – on warming up that we failed to take this lesson to heart.

First raise body temperature

How, then, should we warm up? The following guidance will work for runners. First, raise your body temperature with 5-10 minutes of gentle CV work. Slow-paced running is, after all, a very specific way to warm up your muscles for faster-paced efforts, and there is still a need to prepare the CV system for more strenuous exertions. It is possible to incorporate many of the moves described below into a type of seamless warm-up – *ie* by interspersing them with periods of jogging. But it is probably best to move gradually towards this goal over time – especially if you have always used the traditional, more staid, warm-up approach.

You can increase the speed component of many of the drills as you become more proficient at performing them. This will 'fire up' your nervous system and increase the strength of your muscles for handling more dynamic contractions.

Performing these drills can also reduce the risk of common running injuries, such as shin splints, and can ‘protect’ the knee and ankle joints. Always think about being ‘light’ on your feet.

Aim to perform each of the exercises below over 10-15m, with a walk back or jogging recovery. It should be enough to perform 3-4 reps of each.

- **Lunge walk** – for loosening up the hips, improving leg drive and strengthening the butt and hamstrings. Assume a lunge position and step forwards into another lunge. Keep your chest up, look straight ahead and coordinate your arms with your legs;
- **High knee lift** – for hip flexor and ankle strength. Extend up onto the toes and lift each thigh to a position parallel with the ground as you move forwards;
- **Elbow-to-inside-of-ankle lunge** – for hip flexibility, hamstring strength and stretching out the lower back. Similar to the lunge walk, but extend your trunk forwards over your front leg. If your right leg was in front of you, you would take the right elbow down towards the inside of the right ankle. Watch your balance!
- **Calf walk** – for lower limb strength and achilles flexibility. Extending the ankle on each step will warm up the calf muscles and achilles tendons;
- **Sideways and backwards skipping/running** – for lower limb strength, agility and flexibility.

Other useful warm-up exercises include:

- **Simulated running arm action, standing or seated**. The seated version is also great for specific core stability, as you have to work hard to maintain stability on the ground. Perform for 15-60 seconds, altering your speed of movement;
- **Leg drives**. Lean forwards against a wall, with your hands out at shoulder level and your feet shoulder-width apart and approximately a metre from the wall. Look straight ahead and keep your body straight. Lift your right leg, with the knee bent, until the upper thigh is parallel to the ground. From your hip, drive the leg back, so that your forefoot con-

tacts the ground, then pull the leg back up to the starting position to complete one rep. Perform in sets of 10 on each leg, gradually increasing the speed of the drive;

- **Leg cycling**. Assume the same starting position as for the exercise above, but this time, on driving the leg back, sweep it back up and behind you before pulling it back from the hip to the starting position. Try to keep the foot dorsiflexed – *ie* stretched towards the leg. Perform this exercise slowly at first, gradually building up speed as you become more confident.

Training without shoes

A final thought is – don't wear shoes! No, I'm not recommending that you complete your next lactate stacker session in your socks; but, if weather permits (or you're training indoors), performing the drills described above over very short distances without shoes can be very beneficial. Running shoes prevent the calf and achilles tendons, in particular, from optimally flexing. They also reduce the potential to specifically strengthen these areas. Increasing foot and lower leg strength can make you a more efficient runner.

Here, then, in summary is why adopting a different approach to warming up could improve your sports performance:

1. You'll save time and free up more specific training hours. If you were training five times a week or 250 days a year, warming up and stretching in the traditional manner for 30 minutes at a time would take up a total of 125 hours. That is virtually five days of continuous training time that could be put to much more specific use;
2. The time spent specifically warming up will also improve your running action and specifically strengthen and stretch your running muscles, so boosting your performance. The lower leg is fundamental to running performance, and many of the drills described above will strengthen this region and so, in turn, do wonders for your power generation and force return;
3. You'll be better prepared mentally. A slow warm-up with a sustained period of stretching can switch your mind away from the dynamics of the task ahead. This may be particularly

detrimental before a race or competition, when you'll want to maintain your focus and stay sharp. On a subtler level, your neuromuscular system may not be optimally prepared if you pursue a slower style of warm-up with lots of stretching. The more focused approach will heighten the ability of your muscles to contract;
4. Over-stretching your connective tissue can impair running efficiency and dynamic sports performance. If a runner becomes *too* flexible, perhaps in the hip and upper thigh region, energy can be wasted through inefficient leg drive and knee pick-up. And these negative effects become more pronounced the faster you run;
5. Other research has indicated that the shine is knocked off dynamic activity by too much preparatory passive stretching in the warm-up. Runners' legs need to be 'hard', energy-efficient, force-returning appliances, not spongy, over-absorbent ones. Too much stretching and too great a range of movement can be a bad thing. Recent research indicates that plyometric training for distance runners will develop this energy-efficiency, but so, too, will a more specific warm-up;
6. Hyper-mobile joints can also make you more injury prone, particularly in impact sports.

Having said all this, there are times when 'old school' stretching is okay.

Despite the marginalisation of stretching in the new dynamic warm-up, active, passive and PNF (proprioceptive neuromuscular facilitation) stretching still have a very important role to play in an overall training plan. If you recognise that limitations in your current range of movement are hampering the performance of your sport, you can use these methods to develop the range of movement you require. You should do this periodically, in any case, to reduce muscle shortening and the potential build-up of muscle tightness. Note, however, that this is best done in separate sessions, away from your sport-specific workouts.

John Shepherd

The tale of Eric the endurance runner – or why recovery should be an integral part of training

What follows is a hypothetical story about an endurance runner. Its purpose is to illustrate simple and practical recovery techniques all marathoners can use to help maximise the benefits of training and reduce the risks of illness and injury.

Eric wakes up at 7.45am on Tuesday. Before getting out of bed he checks his heart rate: it is 47bpm – his average for the past few months. He records this in his training diary, along with a rating for quality of sleep. On a scale of 1-4 (bad – okay – good – brilliant), Eric rates last night as no more than 'okay' because he had not found it easy to get off to sleep.

Eric drinks a big glass of water and eats a banana. He then spends about 20 minutes getting ready and watching the news on TV before heading out on his morning run. Eric runs six miles in 34 minutes – a comfortable pace for him. On his return, he immediately drinks 500ml of sports drink and eats an orange. He then completes a leisurely static stretching routine for legs, hips and back before taking a shower.

In the shower, Eric spends some time massaging his neck and shoulders and applying pressure to the iliotibial band down the outside of his leg, where he often experiences tightness. Finally, he spends 30 seconds hosing cold water onto each leg, holding the water jet quite close to the muscles.

The stretch routine and shower takes about 20 minutes, after which Eric is ready for breakfast. He has a big bowl of cereal with milk, a glass of orange juice and a boiled egg with toast.

Being a student, Eric spends the middle of the day in college.

At lunchtime, he eats in the canteen – vegetable soup with a bread roll, followed by chicken casserole with new potatoes, accompanied by plenty of water. In the mid-afternoon, Eric tops up his energy levels with a wholemeal tuna sandwich and an apple.

A tough session

At 6pm Eric heads down to the running track to meet up with his coach and the rest of his training group. He spends 20 minutes going through a core stability exercise routine and then a set of dynamic flexibility exercises before running easily for 10 minutes to warm up. The evening session involves two sets of 8x300m, with 45 seconds' rest. It is quite a tough session, and Eric feels like he is working hard, even though his times are slightly down on a fortnight before, when he last completed this particular workout.

‘When Eric wakes up on Wednesday morning, he measures his heart rate at 58bpm – 11 beats up on the previous day. He rates his sleep as ‘bad’. For these two reasons, Eric decides to give his morning run a miss’

During and after the workout, Eric drinks 500ml of sports drink and 200ml of mineral water. Then, after going through his static stretching routine, he heads home, snacking on a packet of jelly babies on the way. He prepares an evening meal of rice and lamb curry with some salad, and while the curry is cooking he takes a shower, interspersing three minutes of hot water with 30 seconds of cold three times. During dinner he completes his training diary for the day, rating his morning run as ‘good’, but the evening interval workout only as ‘okay’ because of the perceived effort for the times he ran.

When Eric wakes up on Wednesday morning, he measures his heart rate at 58bpm – 11 beats up on the previous day. Again he'd had difficulty getting off to sleep and had awoken during the night, so he rates his sleep as ‘bad’. For these two reasons, Eric decides to give his morning run a miss, even though it had been scheduled into his weekly plan. Instead, he treats himself to a lie-in before breakfast then heads off for college.

On his return home in the mid-afternoon, Eric performs a few stretches then goes through a relaxation technique, focusing on deep breathing. Once relaxed, he spends some time visualising his best race from the previous year, revisiting all the feelings and images he had experienced before, during and after the event. This exercise puts Eric in a great mood and he decides to venture out for a short, easy run.

While running, Eric focuses on posture and relaxed arm action and afterwards he spends 15 minutes performing dynamic flexibility and sprint drill exercises in the local park. Feeling loose and energised, he jogs home, where he drinks 500ml of sports drink and runs a bath. Blessed as he is with a separate shower, Eric keeps the shower running cold and the bath hot, alternating between the two, with three minutes bath to 30 seconds shower.

With free time to kill, Eric arranges to meet a friend at the cinema later and fixes himself an early dinner of spaghetti bolognese with salad. That night, well relaxed, he sleeps easily ('good'), and when he wakes on Thursday his heart rate is back down to 49bpm. At peace with the world, he prepares for his morning run.

During the day, Eric eats and drinks well, as he had on the two previous days, and completes his stretches and core stability exercise routines. In the evening, he does very well with his threshold run and is able to rate both this and the morning run as 'good'.

Friday is Eric's active rest day. Instead of running, he goes to the local swimming pool, where he completes the following routine:

- one length walk forwards;
- one length walk backwards;
- two lengths backstroke;
- stop and stretch calf muscles in water;
- one length lunge walk;
- one length easy breast stroke;
- stop and stretch hamstrings;
- one length high knee walk;
- one length easy breaststroke;
- stop and stretch quadriceps;
- two lengths front crawl.

During this workout, Eric sips from a water bottle placed by the side of the pool and continues sipping while he sits in the sauna for five minutes afterwards.

On Saturday, Eric awakes from a 'good' night's sleep with a normal heart rate. He completes a tough hills session in the morning and a 30-minute steady run in the evening, rating both as 'good'.

Eric performs his stretching and contrast temperature showers after both workouts, takes in plenty of fluids (using sports drinks immediately after the runs) and eats balanced meals composed of fresh ingredients.

This sounds like a simple description of an athlete following a training routine – which is actually the whole point of the story. Although Eric appears to be relying on common sense and his own instincts, he has managed to incorporate a variety of sports science principles and modern recovery techniques into his training week, including:

- daily monitoring of resting heart rate, sleep and training quality;
- self-massage;
- contrast temperature showers;
- stretching – both dynamic and static;
- relaxation techniques;
- visualisation techniques;
- social activity;
- rehydration and refuelling immediately after exercise;
- a high carbohydrate intake;
- a variety of proteins, fruit and vegetables;
- planned days of active recovery;
- pool-based active recovery workout;
- sauna.

These techniques are not expensive: indeed, most are free. To make use of them, all you need is a little knowledge and organisation. For example, stocking up on sports drinks and bottles of mineral water is a useful way of ensuring you can always refuel and rehydrate quickly during and after training. Rapid refuelling allows for faster replacement of energy in the muscles, thus speeding recovery, and is also good for the immune system.

Contrast temperature bathing and showering boosts the circulation and stimulates the nerves, also speeding recovery and helping to remove lactic acid. The hydrostatic pressure on the muscles in the pool session is also beneficial, especially if you follow the kind of light workout suggested above.

Crucially, Eric was prepared to be flexible with his training schedule on the morning he discovered his heart rate was high. Some athletes find it difficult to deviate from a planned training programme, but Eric understood that the high heart rate was his body's way of telling him he had not recovered fully from the previous evening's interval session and therefore needed to relax. He also took a proactive approach to promoting his recovery by performing the visualisation technique and the sprint drills session, thus turning an apparent negative into a positive.

While his overall mileage for the week was reduced because of his easy Wednesday, Eric completed all his quality workouts, the intervals, threshold and hills session. Significantly, after the easy day, Eric rated his training as better than before.

The main take-home message of this story is the importance of self-management in promoting high-quality training. All athletes need to train hard or long, or both, to succeed. By following Eric's example and using self-management techniques to speed your recovery between training sessions, you will optimise the benefits of training, leading to improved performance.

Raphael Brandon

Glycerol – could it be the secret of Olympic marathoner Deena Kastor's success?

One of the surprise results of the 2004 Olympic Games was American Deena Kastor's bronze in the women's marathon. Afterwards it was revealed that she had imbibed a glycerol solution as part of her pre-race preparation in a bid to enhance and maintain hydration in the scorching heat of Athens. Could this have been a factor in her success? Can it really help athletes to keep hydrated? How does it work – and are there any downsides to its use?

Glycerol is a 3-carbon molecule, which is produced naturally in the body as a result of normal metabolism. Although classed as an alcohol, glycerol plays a number of important roles in the body. For example, phosphoglycerides, which consist of a glycerol backbone bonded to two fatty acid chains and another alcohol, are an important component of cell membranes. Glycerol is also used to store fatty acids in the body; in this process, three fatty acid chains are chemically bonded to a glycerol molecule – hence the term 'triglyceride'.

Pure glycerol is a sweet-tasting clear syrupy liquid which increases the concentration, or more technically the osmolarity, of water solutions when it is mixed with them. Because the human body requires the osmolarity of body fluids to remain fairly constant, ingesting glycerol stimulates the absorption and retention of water in order to counter the increase in osmolarity that would otherwise occur.

To put it another way, ingesting a solution of glycerol and

'Ingesting a solution of glycerol and water allows the ingested water to be retained by the body and excreted only when the extra glycerol is either removed by the kidneys or broken down by the body'

water allows the ingested water to be retained by the body and excreted only when the extra glycerol is either removed by the kidneys or broken down by the body [1].

Endurance athletes competing in hot and humid conditions need to maintain maximum hydration, since fluid losses of as little as 1.5 litres can significantly impair performance. Moreover, studies have shown that many athletes do not drink enough to offset dehydration during competition, even with unlimited access to fluid[2].

A temporary state of hyper-hydration can be achieved by drinking lots of water in excess of the body's needs. However, this situation is very transitory because the consequent fall in osmolarity stimulates the kidneys to remove most of the excess water within an hour, requiring frequent trips to the loo, which are not exactly conducive to fast race times!

However, adding glycerol to the water prevents this drop in osmolarity and can prolong the period of hyper-hydration for up to four hours, which explains its use by athletes seeking to enhance endurance performance in hot weather conditions[3].

On the face of it, increasing and maintaining hydration levels in endurance athletes seems a sure-fire way of enhancing hot-weather performance. And there is no doubt that ingesting glycerol solutions does increase water retention by anything up to a litre[4,5].

The question is, however, whether this increased hydration translates directly into superior hot-weather performances. And this is where things start to get a bit less clear.

A study carried out in 1990 investigated whether glycerol hyper-hydration altered sweating, regulation of body temperature and cardiovascular function during exercise in a hot environment (42°C and 25% relative humidity)[3]. Six averagely fit people completed three 90-minute runs at around 60% of their VO_2max after drinking either orange juice, diluted orange juice or glycerol solution.

After glycerol ingestion, subjects produced, on average, 500ml less urine and retained 700ml more total body water than those in the no-glycerol groups. Glycerol-treated subjects also sweated more and had smaller increases in core temperature throughout the 90 minutes of exercise. However, the small sample size and the relatively low work rate used in the trial mean its results should be interpreted with caution.

Two subsequent studies examined the effects of glycerol ingestion in 11 subjects of moderate-to-high endurance fitness[6]. Over a 90-minute period, the subjects consumed either a glycerol solution or a placebo drink; then, an hour later, they cycled at 74% of their VO_2max until they could not maintain their pedalling cadence above 60rpm (revolutions per minute).

Glycerol effects on time to fatigue

As expected, glycerol intake increased pre-exercise body water by 730ml and decreased excreted urine volume by 670ml. But, more importantly, subjects who had taken glycerol exercised significantly longer to fatigue, averaging around 94 minutes compared with just 73 minutes for those on placebo.

The researchers then went on to look at whether these positive effects were still evident when carbohydrate was ingested at the same time, as would be the case for most athletes during prolonged endurance events. Seven highly trained endurance athletes completed the same trial described above, but this time the subjects in both groups also consumed a 5% glucose solution at the rate of 3ml per kg of body weight every 20 minutes.

Analysis of the results showed that, while the glycerol solution still led to the retention of more body water, it was now just 100ml more than for those on placebo. Similarly, the difference in excreted urine volume was reduced to 92ml. Nevertheless, glycerol still prolonged the time taken to reach fatigue (123 minutes compared with 99 for those on placebo!).

Other studies have cast doubt on the efficacy of glycerol, with two subsequent investigations failing to find any significant benefits[4,7]. However, both of these studies used very gentle exercise intensities (around 50% VO_2max), which makes their results less relevant to athletes. An earlier study also showed no benefits, but as well as using a low exercise intensity (50% VO_2max), this one also lacked a pre-exercise hyper-hydration procedure, which makes its results fairly meaningless[8].

On balance, this early research comes down firmly in favour of glycerol. More recent research, however, is rather less clear-cut. Benefits were observed in a study of six endurance-trained cyclists, who ingested either a glycerol solution or the same volume of placebo two hours before undertaking 90 minutes of steady state cycling at 98% of lactate threshold in dry heat (35°C, 30% relative humidity)[9]. The cyclists were also allowed to ingest a carbohydrate drink (6% solution) at 15-minute intervals during the ride. Afterwards, they cycled for a further 15 minutes while their power outputs were assessed.

Glycerol and workload

As expected, pre-exercise urine volume was lower when taking glycerol solution and heart rate was also significantly reduced. And, although the researchers failed to find any significant metabolic differences (such as lactate accumulation) between the glycerol and placebo groups, the work performed in the 15-minute assessment period was 5% higher in those taking glycerol.

Another, arguably more relevant, study on triathletes also found benefits with glycerol use[10]. Seven male and three female triathletes completed two Olympic-distance triathlons two weeks apart, one on a hot day (30.5°C) and the other on a warm day (25°C). The triathletes were randomly assigned to consume either a glycerol solution or placebo, plus a carbohydrate solution in both cases, over a 60-minute period, two hours before each triathlon.

Although there were no significant differences in sweat loss between the glycerol and placebo conditions, glycerol-supplemented triathletes excreted a smaller volume of urine and subsequently retained more fluid than those on placebo.

More importantly, however, athletes on placebo performed significantly worse under hot conditions than those on glycerol by comparison with their performances under warm conditions. The average extra time taken by placebo triathletes in hot weather was 11 mins 40 secs, compared with just 1 min 47 secs extra for those on glycerol.

The researchers also discovered that most of this performance improvement occurred during the final 10k run leg of the triathlon on the hot day. And they concluded that glycerol hyper-hydration may provide some protection against the negative effects of competing in the heat.

However, two studies on glycerol and performance published in 2003 came to rather less positive conclusions. The first compared glycerol and water hydration regimens on tennis performance[11]. Eleven male subjects completed two trials, each consisting of three phases:

1. Hyper-hydration with or without glycerol over 2.5 hours;
2. Two hours of exercise-induced dehydration;
3. Rehydration with or without glycerol over 90 minutes.

In the second trial, those who had taken glycerol reverted to water alone, and *vice versa*. After each phase, subjects completed 5m and 10m sprint tests, a repeated-effort agility test, and tennis skill tests.

As expected, glycerol hyper-hydration increased fluid retention (by around 900ml) by comparison with placebo. However, the exercise-induced dehydration resulted in similar losses of weight (from fluid loss) in both groups. Despite the fact that this loss was modest (less than 3%), the measured sprint times were significantly slower for both groups after phase 2 than after phases 1 and 3, while there were no significant differences between groups for the agility and tennis skill tests.

The researchers concluded that, while the glycerol regimen provided better hydration status than placebo, this was not reflected in performance benefits.

Another study conducted in 2003 set out to compare the effectiveness of glycerol and water hyper-hydration in cyclists working under hot, humid conditions[12]. Seven moderately-to-well trained subjects ingested either a glycerol solution or the same volume of placebo 2.5 hours before a race-simulation exercise, in which they cycled as far as possible over a 60-minute period. While the glycerol group sweated more during the trial, there were no significant between-groups differences in core

'Overall, the current weight of evidence is tilted in favour of glycerol, but only in events where substantial dehydration is likely to be a problem – ie long, strenuous events in hot and humid conditions'

temperature, power output and total distance cycled.

Although there appears to be conflicting evidence about the performance benefits of glycerol hyper-hydration, you might think it fair to assume that it definitely enhances water retention.

However, a recent Canadian study reported on a trained triathlete who retained more water with water alone than with glycerol[13]. The researchers postulated that this might have happened because the plain water was integrated into the body fluid pools more slowly than the glycerol solution. With just one subject, it is difficult to draw firm conclusions, but this study suggests there are some people who respond unusually to glycerol administration, and this may help to explain why some glycerol studies have drawn a blank.

It is fair to say that, for most athletes, imbibing a glycerol solution does produce an increase in total body water. What is less clear is whether this actually enhances performance. This is partly because we don't fully understand how glycerol works in the body. We do know that the kidneys don't excrete glycerol rapidly so that it stays in the body and holds water with it. But more research is needed to find out whether glycerol works by increasing the amount of fluid inside cells or in the circulation.

Overall, the current weight of evidence is tilted in favour of glycerol, but only in events where substantial dehydration is likely to be a problem – *ie* long, strenuous events in hot and humid conditions. However, there is no consensus on the best way to take glycerol solution, or on whether certain kinds of plain water hyper-hydration protocols might offer similar benefits.

So should you take glycerol? Unless your event is long and due to take place in hot/humid conditions, resulting in unavoidable dehydration, there is probably little point. The evidence also suggests that taking glycerol before less vigorous events is not particularly worthwhile.

And where the benefits are likely to be marginal, you should also be aware that glycerol ingestion is associated with such side effects as stomach upsets, headaches and blurred vision at higher doses. If you are tempted to try glycerol, make sure you've tried proper hydration strategies using good old water or fluid replacement drinks first! Glycerol should be considered as a last resort, not the first.

If you do decide to try glycerol, you might like to use the protocol that produced significant hyper-hydration in one of the studies mentioned above [5]. Bear in mind, though, that it involves drinking nearly two litres of fluid, which will lead to a weight increase of 3% for a 70kg athlete and 4% for one weighing 50kg! As a runner, you may find that this extra mass outweighs, quite literally, any potential performance benefits!

Montner's glycerol ingestion protocol, beginning 150 minutes (2.5 hours) before exercise:

- 0 minutes – drink 5ml per kg of your body weight of a 20% glycerol solution (1 part glycerol to 4 parts water);
- 30 minutes – drink 5ml/kg of water;
- 45 minutes – drink 5ml/kg of water;
- 60 minutes – drink 1ml/kg of a 20% glycerol solution and 5 ml/kg of water;
- 90 minutes – drink 5ml/kg of water;
- 150 minutes – begin exercise.

Andrew Hamilton

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Lies, damned lies and statistics: what we know about the incidence of injury, illness and death in the London Marathon

The London Marathon has been a major participant event since it was first run by 6,500 people, mainly novices, in 1981. It now has 32,000 finishers and is the biggest marathon in the world. This article looks at the extent of illness, injury and death associated with the Marathon, and the various factors involved.

Entry to the Marathon is open to anyone over 18. Since 1981, the charity element has expanded significantly, with many participants taking part not because they are traditional runners, but because they have been sponsored by friends and colleagues to raise money for a charity. A survey of runners and charities revealed that more than 75% of participants in the 2002 Marathon were raising money for charity and between them succeeded in raising £32m.

Entrants are sent a medical advice sheet, which gives them responsibility for being fit and well on the day of the race. It suggests they discuss any medical problems with their GP and don't participate without their agreement. It also suggests they surrender their entry if they cannot run 15 miles comfortably one month before the event. Runners who take advantage of this 'sick, lame and lazy' option are guaranteed entry the following year. This medical advice has been widely copied by other races.

First aid services on the day are provided by St John Ambulance, who set out more than 40 first aid posts along the route and at the finish, and two field hospitals at the finish. One of these hospitals has an 'intensive care unit' for more serious collapses, but intravenous fluids may be given at other sites, if necessary.

There is a much larger first aid post in the Isle of Dogs, two thirds of the way round the course. There are also cardiac units at the finish and resuscitation facilities along the course and at the finish.

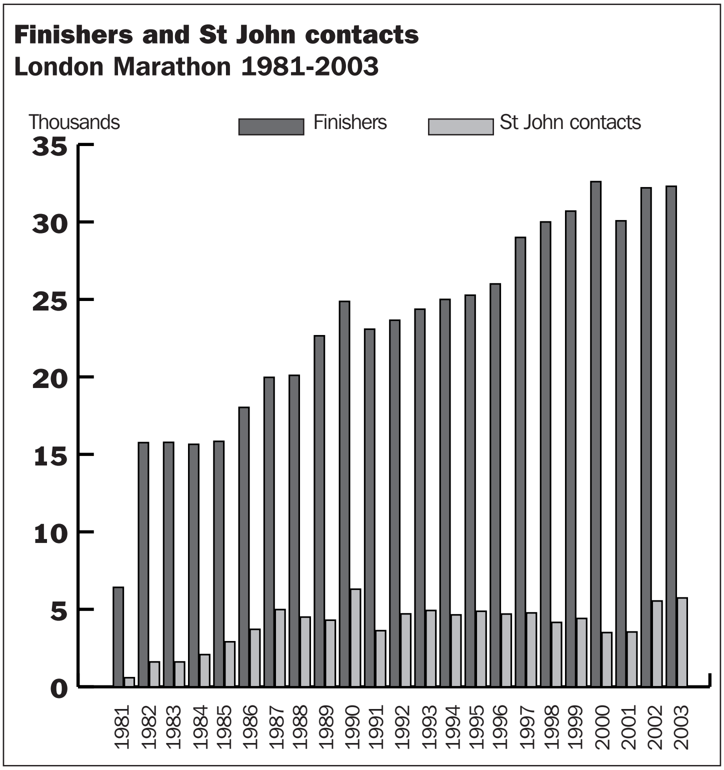
In all, more than 1,000 St John staff volunteer to work on the day, together with other doctors, physiotherapists and podiatrists with an interest in sports medicine, who are recruited to work closely with St John, mainly at the finish. Local 'receiving hospitals' are pre-warned about the race and receive written advice from the race medical director during the preceding week, with St John liaison officers posted to their accident and emergency departments on the day.

A runner who makes contact with first aiders during the race is logged as a 'casualty contact', with diagnosis made by first aid staff, unless the condition requires physiotherapy, medical or podiatric treatment. Each first aid station reports the number of casualties and the primary diagnosis for each.

To minimise lurid newspaper headlines about Marathon casualties, these contacts are divided into categories which clarify the seriousness of the various conditions involved. These include:

- *Social contacts* – who stop and ask for such help as a drink, a shoelace or a dressing to treat themselves;
- *Musculoskeletal contacts* – with cramps or painful joints, bones or muscles;
- *Topical contacts* – with blisters, abrasions, runner's nipple, skin chafing or subungual haematomas (blood clots under the toenails);
- *Constitutional contacts* – who collapse, have chest or abdominal pain, diarrhoea, fits, vomiting etc.

The St John Ambulance reports are supplemented by enquiries to the designated receiving hospitals, which are asked to flag up all Marathon accident and emergency cases.



In 2000, when 32,600 runners completed the race, 4,633 St John Ambulance and 38 hospital contacts were recorded. By comparison, in 1987, when 19,970 runners completed the race, there were 4,984 St John Ambulance contacts and 10 hospital contacts. Totals for the 20 years show a hospital contact rate of 0.13% (one in 787). Hospital admissions are roughly 10% of the hospital contacts, but are increasingly difficult to define, as runners may spend many hours in accident and emergency.

Only those deaths, or collapses leading to deaths, that occur during the Marathon or within the finish area of the race, are considered Marathon deaths. Seven cardiac deaths have been reported in the London Marathon: five from severe coronary heart disease – in 1991, 1994, 1995, 1997 and 2003 – and two with hypertrophic cardiomyopathy (HCM, a chronic disorder

Breakdown of diagnoses		**%**
Social ('vaseline')	97	2
Constitutional	197	4
Topical ('blisters')	731	15
Muskuloskeletal	3,963	79
Total	**4,988**	**100**

Breakdown of 'constitutional' casualties		
Chest pain/breathing	3	2
Headache	7	4
Dehydration	14	7
Collapse	17	9
Feeling cold	25	13
Nausea/vomiting	45	23
Tired	86	44
Total	**197**	**100**

Figures from the 1987 London Marathon

affecting the heart muscle) – in 1990 and 2001. Five successful cardiac resuscitations have taken place (in 1983, 1988, 1990, 1997 and 1998); all patients had coronary heart disease and were subsequently discharged from hospital. In the millennium race, a young man collapsed at the finish complaining of neck pain and died the following day in hospital following a diagnosis of subarachnoid (brain) haemorrhage.

'The overall mortality rate from the 20 years is one in 67,414, or roughly one death for every two million miles run'

The overall mortality rate from the 20 years is one in 67,414, or roughly one death for every two million miles run.

The medical director of the race is updated on the casualty contact numbers and the numbers taken to hospital by St John Ambulance. The director can check the more serious medical problems at hospitals designated to receive casualties from the race. However, unless specifically notified, he will not be aware of casualties who bypass the race casualty control system and go to other hospitals, or of those who arrive at the designated hospitals later in the day without wearing running clothes and a race number, and thus are not recorded as race casualties.

The more attractive, obvious and frequent the aid points are in a marathon, the more likely it is that a tired, cramping,

Finishers and hospital contacts

Year	Finishers	Seen in hospital
1981	6,418	11
1982	15,758	34
1983	15,776	19
1984	15,649	15
1985	15,841	6
1986	18,031	5
1987	19,970	10
1988	21,100	38
1989	22,651	19
1990	24,871	20
1991	23,080	24
1992	23,657	15
1993	24,369	20
1994	25,000	40
1995	25,272	40
1996	26,000	90
1997	29,000	27
1998	30,000	59
1999	30,700	35
2000	32,600	35
2001	30,071	25
2002	32,200	41
2003	32,300	58

blistered runner will make a 'pit stop' and become a marathon medical statistic. Some races offer psychotherapists at the start and massage therapists at the finish, which increases the potential for collecting casualty numbers. Definition of an injury and the numbers are, therefore, contentious.

Most runners suffer from minor injuries, such as cramps, blisters, skin chafing and subungual haematomas. The medical staff may be unaware of many of these injuries, especially as the successful runners are euphoric, anxious to go home and usually convinced that they can handle the problems themselves. The staff lose contact with participants immediately after the race as the runners disperse across the UK and to several other countries, taking their non-immediate medical problems to a multiplicity of doctors and physiotherapists. This makes a survey of the impact of the Marathon on medical providers even more difficult than a questionnaire to runners.

The sports medicine definition of an injury as something that prevents training for a defined number of days is impossible to apply when severe muscle stiffness is almost universal and full training may not be part of the runner's post-race agenda. Aches and pains and severe delayed-onset muscle stiffness are common after a marathon and may only be appreciated as significant injuries if they fail to subside in the following two weeks. Some runners may experience severe pain for days after a marathon when walking up or down stairs.

Marathon deaths may be random

Deaths occurring during or shortly after a marathon are naturally blamed on the event, particularly by the media, but may, in fact, be random and possibly unrelated. For example, a known epileptic ran the Marathon, went home, suffered a fit in his bath while nobody was in the house, and drowned. If the fit was an unlikely event, precipitated by running the Marathon, it could legitimately be blamed on the race; however, without knowing the frequency of the fits, whether or not the man had taken his medication and other factors, the culpability of the Marathon is indirect.

Another runner died in his sleep 36 hours after completing the Marathon. He told his wife how well he had felt during and after it. He went swimming the next day, but his wife awoke to find him in the throes of a terminal anoxic fit (a fit caused by lack of circulating oxygen) that night. He was found to have HCM at the post-mortem. A claim was made in the press that the Marathon caused his death, and it is conceivable that a lingering biochemical or endocrine effect of prolonged exertion precipitated a fatal cardiac arrhythmia.

This raises many questions, such as for how long after a marathon can the run itself be blamed for death, when in the presence of a lethal condition that can kill at any time? Deaths caused by HCM can occur at any time and an infrequent or unusual event may be blamed as the cause. Epileptic fits may occur in close proximity to running a marathon, and a statistical analysis of fit frequency and the total number of epileptics running the marathon would be needed to draw sound conclusions. If HCM has an incidence of one in 500, and people with this condition are not inhibited from running, it can be calculated that about 1,000 runners with this condition have run the Marathon and only two have died during the race.

Questionnaires have been used to assess marathon morbidity in locally based marathons, but cannot be applied to major international races. They have a notoriously poor return. For example, a small survey of British doctors running the London Marathon in 1996 showed that less than 20% returned a questionnaire after the race, making the finding of a low percentage reporting upper respiratory tract infections in the week after the marathon invalid. The anticlimax and fatigue following completion of a marathon appeared to militate against completing and returning a questionnaire.

The totals of St John Ambulance casualty contacts are the numbers declared the day after the Marathon, once St John Ambulance has had returns from all station crews who disperse to much of southern England after the race. This number is sometimes subsequently corrected, and discrepancies may occur when spectators are included in some returns and not in others. The total number of runners who make contact with the medical first aid posts may, if they outnumber the first aid provision, be under-reported, as treatment may take priority over reporting if a first aid post becomes swamped.

Accurate reporting of race casualties also becomes a problem where the fallen runner may have more than one diagnosis, *eg* exercise-associated collapse, plus blisters, plus subungual haematoma, plus groin chafing, but is only reported under the presenting complaint of collapse. A further complication is that the same runner may make contact with more than one aid station, making pit stops for ‘repairs’ at several and being counted as a fresh casualty or contact at each point. However, the multiple reporting error was assessed in one marathon and found to be a minor source of error in the grand total.

Casualties are assessed rapidly by first aiders and only very few are seen by trained diagnosticians. The diagnoses are, therefore, anatomical rather than accurate, where pain is the prime complaint. A painful shin may be a fatigue fracture, but there is usually no easy follow-up. Exercise-associated collapse may be registered under a variety of names, eg hypothermia, collapse and severe fatigue, even in hospital cases.

In summary...

Based on 23 years' experience, the approximate overall risks of running the Marathon are:

- contact with St John: 1 in 6;
- contact with a hospital accident and emergency department: 1 in 800;
- hospital admission: 1 in 10,000;
- death: 1 in 67,414 – a risk which is comparable to many daily activities.

Dan Tunstall Pedoe

Adapted and updated from 'Morbidity and Mortality in the London Marathon', a paper in Marathon Medicine, RSM Press Ltd, £19.95, 2001 www.rsmpress.co.uk/bktunstall.htm.

Running is a poor man's sport: a prominent distance coach reflects on the inexorable decline in Northern European endurance running

In 1990 I was coaching a small group of ex-University runners, the best of whom was Richard Nerurkar. The previous year he had made the British team for the World Cross-Country Championships, but had finished only 5th in the 10,000m trial for the Commonwealth Games. Ahead of him were such people as Tim Hutchings, who had finished second in the World Cross-Country, and Eamonn Martin, who went on to beat Moses Tanui to the Commonwealth title.

Richard knew he had to train very hard if he was to make the British team for the European Championships. He had been averaging around 100 miles a week since his year in Russia in 1985 and had improved his 5,000m time to 13.27; so we reckoned he should be able to aim for close to 28 minutes in the AAA championships, which should be good enough to make the team.

As it turned out it was, and he did, and when he went to the Europeans in Split he was in second place at the bell, only to get pushed back to fifth on the last lap.

The following year, Richard set his sights a bit higher and trained for the World Championships in Tokyo, knowing that there would be only one day's rest between the heat and the final. On a Tuesday in May, he ran 28.55 on our school cinder track, paced by our cross-country team; then on the Thursday he ran 28.39 on the Tartan track in Swindon, paced by Ian Manners.

When it came to the heat and humidity of Tokyo, Richard was well prepared, qualifying easily for the final, then running a personal best of 27.57, but once again being outsprinted in the fight for the medals. By then we knew that his real future lay in the marathon, and after a disappointing run in the 10,000m final at the Barcelona Olympics in 1992 that became his goal. A year later he won the World Cup Marathon in 2:10:03, the first major marathon title for a British runner since 1976, and he went on to finish 5th in the Atlanta Olympics and to set a personal best of 2.08.36 in London in 1997.

‘Top-class marathon runners come from a track background, and it is very rarely that a world-class marathoner is not able to run a very good 10,000m’

This brings me, in a rather long-winded way, to my first point: that top-class marathon runners come from a track background, and it is very rarely that a world-class marathoner is not able to run a very good 10,000m. Steve Jones switched straight from the 1984 Olympic 10k to breaking the world marathon record in Chicago. Richard Nerurkar ran his best 10k (27.40) only six weeks after his first marathon.

From a national point of view, it is obvious that when you have high standards in the 5k and 10k, more good runners are forced up to the marathon. In 1989, Richard’s 13.27 5,000m put him only 9th in Britain, so he naturally chose the 10k. However, that same time in 2003 would have put him top of the British 5,000m rankings.

If you were a 28.30 10k runner in 1990 you would not have made the top 10 in Britain, but in 2003 you would have been second. Human nature being what it is, this means that fewer runners of real quality are likely to take to the marathon because they can win national titles and international vests running shorter distances – and can also race internationally far more frequently during the year.

Before we begin to lament our declining standards and to agonise over what can be done about them, let us put things in perspective. I have been on the running scene since the midfifties; my first hero was the Czech runner Emil Zatopek, who won those amazing three gold medals in Helsinki. I can remember, too, when Hungary was the dominant force in distance running, holding all the world records from 1,500m upwards.

Before that, Finland and Sweden were the strongest nations in the world. They were followed by runners from the USSR – Kuts and Bolotnikov – and the Poles, notably Krzyszkowiak. Only one man from these six nations, Sergiy Lebed of the Ukraine, approached world class in distance running in 2003. And in the whole of Europe, only four men made the world top 50 at 5,000m, five at 10,000m and seven in the marathon. The truth is that men's distance running is dominated by Africans, and it is only a matter of time before the same applies to women, too.

'What about Paula', I hear you cry, 'and Sonia O'Sullivan and Benita Johnson? Does this not prove that the men are simply not training hard enough?' No, all it shows is that, for cultural reasons, only a few African women are allowed to develop their talent, compared with thousands of men and boys in Kenya, Ethiopia, Morocco and South Africa.

The situation is not going to get any better either, because other African countries are following the same path. Uganda, Eritrea and Rwanda won team medals in the 2004 World Cross-Country and only one European nation, Great Britain, won a team medal.

So in European terms Britain is not doing badly, but there are still two questions to be answered:

- Why are the Africans so much better than the rest of us, and
- Why are British (and European) standards declining?

Briefly, the answer to the first question is that running is a poor man's sport, needing only talent and hard work. Africa has millions of poor men and they are willing to work hard because they have nothing to lose. By contrast, the young men of the Western world look more towards the affluent sports – skiing, sailing, motor racing, biking, rowing, triathlon and snowboarding.

'Africa has millions of poor men and they are willing to work hard because they have nothing to lose. By contrast, the young men of the Western world look more towards the affluent sports – skiing, sailing, motor racing, biking, rowing, triathlon and snowboarding'

The decline in Northern European running has its roots in affluence. In my day, distance running strength came from the clubs in the big cities – Gateshead, Manchester, Liverpool, Portsmouth, Coventry and Derby. It was a sport that cost very little but gave one the chance of success and the glamour of travel. The car workers of Coventry won a stack of international medals thanks to the efforts of Basil Heatley, Brian Kilby, Bill Adcocks and Dick Taylor, but these days the glamour of travel is a far less elusive commodity.

Running is part of the consumer society

The fact that more and more people are running has little or no connection with success at international level, because the motivations are not the same. Just as the Ugandans are following the same path as the Kenyans, the British are following the same path as the Swedes and Finns. We cannot swim against the tide of history. We have more food, more leisure, more money, more machines and more obesity, but also more diet books, more discos, more gyms, more sports scientists and more leisure clubs.

Running is no longer a sport for hard-training introverts; it is part of the consumer society – a leisure activity involving a bit of gentle exercise, a bit of socialising and quite a lot of buying of designer gear.

This is not to say that we will never produce any more great runners, but they are going to be few and far between. The very gifted will be nurtured and polished with the best of scientific support and marketed like expensive commodities. We have seen this happen with Paula Radcliffe in Britain and Carolina Kluft in Sweden, and it could happen in men's marathon running too, if the talent is unearthed.

What will it take to produce a world-class British marathon runner? First, he must have basic running ability – which means a high VO_2max, a lean body, a low pulse rate and the ability to run 5,000m in 13.20. Such a person will probably show up at under-17 or under-20 level and win medals in European junior competition. Second, he must have both the willingness to train hard and the physique to absorb a high volume of hard training without getting injured. Third, he must be able to develop the unique mindset of the marathon runner, combining an overwhelming desire to win with the patience to wait for two hours before striking.

What sort of training will this athlete be doing? More than 20 years ago, in my book *The Complete Distance Runner*, I set out a schedule of '1990 training' for the person who was going to run 27 minutes for 10k, as follows:

Sun: am 20 miles, pm 6 miles, inc 12 x 150 fast stride;
Mon: am 8 miles steady, pm 10 x 1k in 2.45;
Tues: am 8 miles steady, pm 10-12 miles fartlek;
Wed: am 8 miles easy, pm 8 x 800m in 2.07 plus 10 x 400 in 61-63 secs;
Thur: am 8 miles easy, pm 3 sets of 10 x 250m fast stride;
Fri: am 5 miles easy, noon 5 miles fast tempo run, pm 5 miles easy fartlek;
Sat: am 5 miles easy, pm club track races.
Total distance – 120 miles

Compare this with a typical hard week's training that Richard Nerurkar was doing in his marathon preparation in the mid-nineties:

Sun: am 22 miles, starting easy, finishing fast, pm gym work plus swim;
Mon: am 5 miles easy, pm 7 miles inc sprint drills + swim;
Tues: am 6 miles steady, pm 10 miles, inc 6 at threshold pace;
Wed: am 10 miles inc 3 x 3000m in 8 mins 30 (5 mins recovery), pm 6 miles easy + swim;
Thur: am 5 miles steady, pm 6 miles easy + 10 x 100m stride;
Fri: am 6 miles, pm track workout, 10 x 1000m, av 2.45 (2.30 recovery);
Sat: am 10 miles steady, pm 7 miles.
Total distance – 120 miles plus swimming and exercises

My view is that this is about as high as one can go in mileage terms without the effort becoming counterproductive.

However, when in altitude training camps Richard would often put in an early morning run of 3-4 miles, bringing the weekly mileage up to 140. In both the Kenyan and the Mexican training camps that we have attended, three sessions a day and 150 miles a week was considered pretty normal.

How can this be improved on? The answer lies in better science, with more efficient monitoring of an athlete's state of fatigue. Daily monitoring of stress hormones in the blood would enable coaches to pile on the work when athletes are recovering quickly and ease off when they start to become over-tired.

A good training camp regime – with good food, pleasant company, regular swimming, sauna and massage – enables the runner (and even his coach) to handle a much greater training volume than can be performed by an unsupported athlete. We just have to find the young men who are willing to try it.

In 1990, the world marathon best stood at 2:07:15 and the British marathon best at 2:07:16. Today the world best stands at 2:04:55 and the British best... has stood still! Nevertheless, we are starting to see an improvement. After years of decline, British men's marathon running reached an all-time low in 2003, in the same year as our women's marathon performance reached an all-time high. Paula Radcliffe's 2:15.25, an amazing world record, was 16 seconds faster than the fastest time by a British male – Mark Steinle, who had run 2.09 the year before.

In the 2004 London Marathon, our best performance was a steady 2.13 by John Brown, but 12 other British men went under 2.20. This improvement was brought about by a well-organised series of training weekends put on by UK Athletics, and by the event organisers providing pacemakers for a 2.15 (Olympic qualifying) pace. Let us hope that this is not a temporary halt in the slide, but the first step towards regaining the ground we have lost over the last 15 years.

Bruce Tulloh

WHAT THE SCIENTISTS SAY

Reports on recent marathon-related studies by Isabel Walker

Metabolic markers of peak performance

Differences in the metabolic response to exercise between sedentary and trained subjects are well-rehearsed. And much is now known about the differences between moderately- and highly-trained athletes. But what separates the high-level performers from those at the very top of the game?

That is what a French research team set out to investigate with a small-scale study comparing blood chemical parameters in 14 top-class male marathon runners from French and Portuguese Olympic teams a few weeks before they were due to compete in international marathon events.

The subjects were asked to give the velocity they thought they would reach during their next event, and a 10k run at this velocity was used for testing purposes. The mean extrapolated performance time for the marathon was 133.7 (2:13:42) minutes, with a range from 126.9 to 142 minutes.

After a 15-minute warm-up, subjects were equipped with heart and gas exchange monitoring apparatus. Fingertip blood samples were taken at rest (before warm-up) and immediately after the 10km test. They were then analysed by a technique known as 'Fourier-transform infrared spectrometry', which is acknowledged to be the best method of analysing the global metabolic response to exercise.

In the event, several biochemical parameters of the metabolic response to a 10k run at individual marathon velocity were found to be strongly linked with the best performance. These were:

1. a slightly, but significantly, higher increase in blood glucose concentration;
2. improved fatty acid selectivity, with longer and/or less unsaturated fatty acids predominantly metabolised;

3. higher fatty acid uptake by skeletal muscle, as indicated by a more pronounced decrease in blood triglycerides and a proportional glycerol concentration increase;
4. higher amino acid production and blood release, correlated with an apparent breakdown of several proteins for amino acid supply to skeletal muscles.

'These metabolic adaptations to intense endurance training probably explained in part the difference between high and top-class marathon performances,' conclude the researchers. '... the best runners have enhanced both carbohydrate, lipid and amino acid metabolisms to improve energetic supply to skeletal muscle during exercise.'

Japanese Journal of Physiology, 52, 181-190, 2002

Injury risks for marathon 'virgins'

Men and women embarking on marathon training programmes are at significant risk of injury because of their lack of experience, according to a major study carried out in Texas – the first to describe the baseline characteristics of a large representative group of non-elite athletes and their relationship to injury risk factors.

A four-page questionnaire was completed by 1,548 of 2,314 people registering for the 1998-99 Houston Fit Marathon Training Programme, a 25-week running or walking programme designed to help individuals achieve their fitness goals while training for the Houston Marathon.

Key data revealed on analysis of the questionnaires was as follows:

- most (63%) of the sample were female and most runners of both sexes were concentrated in the 20-50 age range;
- 3.5% (mostly women) were underweight and 35.6% (mostly men) were overweight or obese;
- the mean number of years of running experience was 6.2 and only 10.2% had competitive running team experience, in most cases dating back to school days;

● the majority (52.3%) had not previously trained for a marathon and, of those who had, 28% had not completed a marathon;
● about a quarter of the sample either had done no prior running or had been running for one year or less;
● just over 16% (more women than men) had been physically inactive in the three months prior to starting the programme;
● 38.1% reported having had an injury during the previous three years and 35% of all injuries were still causing symptoms.

'The most significant finding in this study,' note the researchers, 'is that the majority of those in a training programme to complete a marathon are not elite, well-trained, experienced runners.

'Training techniques that may be associated with injury are more prevalent in those with relatively little running and marathon experience. ... Thus we suggest that training programmes should take measures to establish baseline fitness, educate on injury prevention training techniques and set appropriate fitness goals to accommodate for the training needs of participants and increase the chance for successful outcomes.'
Clin J Sports Med 2002; 12: 18-23

Carbohydrates and perceived exertion

Does carbohydrate supplementation exert an ergogenic effect during marathon running? That is the question US researchers set out to answer in a study of 98 male and female entrants to the 1999 Charlotte Marathon and the 2000 Grandfather Mountain Marathon in Boone, both in North Carolina.

The highly experienced (but non-elite) participants, ranging in age from 21 to 72, underwent a series of blood and anthropometric tests on the morning of the race and were then randomly assigned to one of two conditions:
● supplementation with a 6% carbohydrate drink, with each runner ingesting 650ml about 30 minutes before the start of the race and approximately 1,000ml at hourly intervals during the event;
● the same amounts of an inactive placebo drink, identical in appearance and taste to the carbohydrate solution.

A chest heart rate monitor was attached to each runner and research assistants, positioned every 3.2k along the racecourse to deliver the drinks, recorded heart rates and ratings of perceived exertion (RPE) at the same time. After runners crossed the finish line, blood samples were collected from each within five minutes.

Key findings for the two races combined were as follows:

- Race times for both the carbohydrate and the placebo group were slower than their personal bests of the previous year due to the hilly terrain of both these marathons. Although race times did not differ significantly between the groups, the placebo group was about 15 minutes slower by comparison with these earlier PBs than the carb group;
- RPEs during running did not differ significantly between the two conditions, although there was a non-significant trend towards a higher RPE during the later portion of the race with placebo;
- Runners in the carbohydrate group were able to run at a higher intensity – *ie* at a higher percentage of their maximum heart rate – particularly during the final 10k;
- Despite the similarity in RPE between the two conditions, there was a significant decrease in plasma glucose and insulin, concomitant with an increase in plasma cortisol and growth hormone, with placebo compared with the carbohydrate condition.

Based on the evidence of their previous laboratory-based studies, the researchers had hypothesised that RPE would be lower – *ie* running would feel easier – with carbohydrate supplementation. A possible explanation for their failure to replicate this finding 'in the field' is that experimental outcomes during an actual race can be easily affected by many extraneous variables, including weather, terrain and motivation as well as variations in the intensities at which the runners were performing from point to point.

'These findings suggest,' they conclude, 'that the attainment of a greater percentage of maximum heart rate at a given RPE can be attributable to a sustained supply of carbohydrate energy substrates to the exercising muscle.'

But they add: 'During prolonged strenuous exercise, where intensity varies from point-to-point as in marathon running, it

appears that factors other than carbohydrate energy substrate availability play an important role in mediating the strength of perceived exertion.'
Med Sci Sports Exerc 2002 Nov; 34(11): pp1779-84

Why distance running can be bad for bones

Distance running increases a woman's risk of osteoporosis and consequent fractures, according to a British study. London-based researchers studying 52 female endurance runners aged 18-44 found, to their surprise, a negative association between running distance and bone mineral density (BMD) in the femoral neck and lumbar spine regions.

The participants in the study, whose chosen distances ranged from 1,500m to marathon, had been exercising for an average eight hours per week at recreational to elite level, with a mean distance run per week of 32k (range 5-70k). They filled in detailed questionnaires about their training, dietary, health and menstrual habits and were subjected to a range of anthropometric tests, including bone densitometry to assess body fat percentage and BMD.

Key results were as follows:

- Two of the 52 women were classified as osteoporotic at the lumbar spine and one at the femoral neck. Osteopenia (bone deficiency) was diagnosed in nine and six of the participants at the lumbar spine and femoral neck respectively;
- Distance run was negatively associated with lumbar spine BMD, with participants who ran longer distances appearing to have a lower BMD (lower by 1% in those running a further 10k/week);
- Distance run was even more negatively associated with femoral neck BMD, which was lower by 2% in those running a further 10k/week;
- Body mass (but not body fat percentage) was positively associated with BMD, suggesting that it is the lean component of body mass that is important for maintaining bone;
- No significant association was found between menstrual irregularity and BMD at either site;

● Although no direct relationship was found between energy intake and BMD at any site, femoral neck BMD was positively associated with magnesium intake but negatively associated with zinc intake – the latter being a surprising finding.

The researchers had worked on the hypothesis that, since physical activity has been shown to exert a positive effect on BMD in postmenopausal women, it would have an even more protective effect on younger women training much harder.

Why was this theory not borne out in practice? The researchers suggest it is probably connected with the relatively low forces applied to the limbs during running – forces which, according to previous research, are crucial to BMD.

'Athletes involved in sports and training where forces applied to the limbs are in excess of 10 times body weight (gymnastics, weightlifting and volleyball) have been found to have higher BMD than those involved in sports where forces are only in the range of 5-10 times body weight, such as endurance running,' they explain.

'It seems that, although running includes many more cycles of foot strike and thus force application than these other sports, the lower loads are not as stimulatory to bone accretion. This may explain our findings that longer running distances appear to be associated with lower BMD, because the longer distances covered would be associated with lower intensity exercise and thus lower forces being applied to the limbs.'

Br J Sports Med 2003; 37: 67-71

Why stiffer legs make running easier

Plyometric training enhances running economy – and hence running performance – by stiffening the legs. That's the fascinating conclusion of an Australian study of male distance runners.

While VO_2max has previously been considered the best predictor of endurance performance, other variables, including running economy (RE), are now thought to be better predictors in trained athletes.

Traditionally, long slow distance training has been the favoured training method for improving RE – defined as the steady-state oxygen requirement for a given submaximal running speed. But recent research has focused on the beneficial effects of various forms of strength training.

One such study found that simultaneous plyometric (explosive-strength) and endurance training produced a significant improvement in 5k running performance in well-trained endurance athletes, although the exact mechanism for this improvement was unclear.

The authors of the current study set out to test the increasingly popular theory that the energy cost of running is inversely related to the stiffness of the propulsive leg – *ie* the stiffer the leg, the lower the energy cost. They hypothesised that by increasing stiffness through plyometric training, their subjects would achieve greater propulsion for the same or less energy cost, thereby improving economy and consequently boosting running performance.

The 17 distance runners in the study were randomly assigned to one of the following groups:

- An experimental group, who completed six weeks of plyometric training in conjunction with their normal running training. The plyometric programme involved two sessions per week for the first three weeks and three sessions per week for the final three, with exercises consisting of various jumps, bounds and hops in both horizontal and vertical planes;
- A control group, who just carried on with their normal running training.

The following variables were tested at the beginning and end of the study: lower leg musculotendinous stiffness (MTS); maximum isometric force; rate of force development; 5-bound distance test (5BT); counter movement jump (CMJ) height; RE; VO_2max; lactate threshold; 3k running time.

Predictably, the CMJ height and 5BT results for the experimental group improved significantly, confirming the effectiveness of the plyometric training programme.

More interestingly, the runners in the experimental group also demonstrated significant changes in the following:

- 3k run time, which improved by 2.7% over the course of the study period;

- RE, which improved for each of three velocities tested – by a mean of 6.7% for 12k/hour, 6.4% for 14k/hour and 4.1% for 16k/hour;
- MTS, which increased at three different percentages of maximal isometric force, most dramatically at the heaviest load (75%), when increases of 14.9% for the left leg and 10.9% for the right leg were recorded.

No significant changes were recorded for the control group in any of these variables. And no significant changes were recorded for either group in VO_2max or lactate threshold.

In the absence of these latter changes, and any change in body mass, the researchers speculate that the experimental subjects' improved running performances must have been due to the improvement in RE.

'The mechanism underlying this change appears to be a result of an increase in lower body MTS with plyometric training, leading to improved reactive power and a decreased energy cost of running,' they conclude.

'Further research is needed to establish whether such running improvements derive from an increased stride length or stride frequency, or a combination of the two.'

Eur J Appl Physiol, vol 89, pp1-7, 2003

Nature and nurture in Ethiopian endurance running success

In the increasingly competitive world of international sport, identifying the key predictors of success has become a major goal for many sports scientists. And nowhere has the hunt been more focused than in East Africa, where the overwhelming success of male endurance athletes has kept the nature v nurture debate simmering.

Saltin's famous study comparing Kenyan and Scandinavian athletes suggested that it was the distance the Kenyans travelled to school on foot in childhood that gave them an edge in endurance athletics.

That theory has now received further backing from a major British study comparing the demographic characteristics of

Ethiopian athletes with non-athlete controls from the same country.

An additional fascinating finding was that elite Ethiopian distance runners are ethnically distinct from the general Ethiopian population, raising the possibility that genetic factors might also be involved.

Questionnaires seeking information on place of birth, spoken language (by self and grandparents), distance from and method of travel to school were given to 114 male and female members of the Ethiopian national athletics team and 111 Ethiopian controls, none of whom were regularly training for any track or field athletic events. The athletes were separated into three groups for comparison: marathon runners (34), 5-10k runners (42) and other track and field athletes (38).

After analysis, the main findings were as follows:

- In terms of regional distribution, there was a significant excess of athletes, particularly marathoners, from the Arsi and Shewa regions of Ethiopia. 73% of marathon runners hailed from one of these two regions, compared with 43% of 5-10km runners, 29% of track and field athletes and just 15% of controls. To put those figures in context, Arsi is the smallest of Ethiopia's 13 regions, accounting for less than 5% of the total population, but housing 38% of the marathon athletes in this study;
- The origin of language of all the athlete groups differed significantly from that of the controls. Three separate language categories were used: Semitic, Cushitic and Other; and Cushitic was significantly more predominant in each of the athlete groups than among the controls. The effect was most pronounced in the marathon group, where 75% spoke languages of Cushitic origin compared to 30% of controls;
- In terms of distance travelled to school, the marathon athletes differed significantly from all other groups. 73% of marathoners travelled more than 5k to school each day, compared with 32-40% of the other groups. And marathoners were much more likely to run to school each day than the other groups (68% v 16-31%).

Where does this leave the nature v nurture debate? The findings about travel to school undoubtedly point to environmental influences, as the researchers acknowledge.

'…the results implicated childhood endurance activity as a key selection pressure in the determination of Ethiopian endurance success,' they say. 'With the prevalence of childhood obesity in the United States and Great Britain at an all-time high, and physical activity levels among such populations in stark contrast to the daily aerobic activity of Ethiopian children, these factors may offer an explanation for the success of East-African athletes on the international stage.'

On the other hand, the findings about regional and ethnic origins point to genetic influences. Or do they? The regions of Arsi and Shewa are situated in the central highlands of Ethiopia, intersected by the very same Rift Valley that has been implicated in the success of Kenyan endurance runners. This may seem to support a link between altitude and endurance success. But it doesn't explain why Arsi is also considerably overrepresented in track and field athletes (18%), who would not be expected to benefit from living and training at altitude.

The researchers put forward an alternative, somewhat more prosaic, hypothesis. 'One of the senior Ethiopian athletic coaches informed the investigators that most of the marathon athletes would be found to be from Arsi,' they explain. 'If those in charge of athletic development believe this, it may cause a self-fulfilling prophecy through talent scouts focusing more attention to this region or through increased regional development of athletics.'

What of the findings about language? The fact that most of the marathoners spoke languages of Cushitic origin (mostly Oromigna, the language of Oromo people) 'may reflect a high frequency of potential "performance genes" within this particular group.

'However, it is much more likely,' the researchers add, 'that the distinctive ethnic origin of the marathon athletes is a reflection of their geographical distribution, as primarily Oromo people populate Arsi.

'Although not excluding any genetic influence,' they conclude, 'the results of the present study highlight the importance of environment in the determination of endurance athletic success.'

Med Sci Sports Exerc, vol 35, no 10, pp1727-1732

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