COACHING YOUNG ATHLETES

A SPECIAL REPORT FROM

PEAK PERFORMANCE

The research newsletter on stamina, strength and fitness

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Published by Peak Performance Publishing

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

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

ISBN: 1-905096-02-X

Publisher Jonathan A. Pye
Editor Bob Troop
Designer Charlie Thomas

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From the publisher

I must admit I heaved a sigh of regret when I read this special report. If only it had existed 20-odd years ago, and been read by my parents or even the PE teacher at school, I might have been David Beckham by now! In my day they never thought that kids could be trained as young athletes – we were just sent out to horse around in the playground and the only advice we received was 'Any fighting and you'll get six of the best'. At least that's the way I remember it. Or perhaps, come to think of it, I was meant for other things.

This special report on the care and training of young athletes has been written by the *Peak Performance* team of experts, including coaches, athletes and fitness specialists. It begins with words of wisdom from Raphael Brandon: 'Remember not to treat young athletes as adults in miniature' and the whole report continues in the same vein: how to bring out the best in kids and help them to achieve their athletic potential. If they want to, that is. As Bruce Tulloh points out later in the report, kids can have talent and drive and enthusiasm, and then, suddenly, decide to do something quite different. And you, if you're a parent or coach, have to let them. That's what Bruce himself did.

I hope you enjoy this special report and find it useful.

Jonathan A Pye
Publisher

A fitness specialist says: if you're training child athletes, remember not to treat them as adults in miniature

Many coaches are involved with training young athletes. What they should be aware of, however, is that training theory and coaching methods are mostly based on the physiology of adults, which has been extensively studied. This can create a problem because, in fact, the exercise physiology of children is different from that of adults. Children are not mini-adults. Rather, they have a developing physiology, from early childhood to late adolescence. This means they have different capabilities for, and adaptations to, exercise. For this reason, young athlete training programmes should not be just scaled-down versions of adult training. The purpose of this article is to help coaches become aware of the kinds of training that are right for young athletes and the kinds of training that aren't.

Growing...

Children grow at uneven rates. The fastest rate of growth occurs in the first two years when a child will reach half full height; the growth rate then slows until the adolescent spurt, which lasts for about two years. This takes place, on average, at 10-12 years for girls and 12-14 years for boys. After this, growth rate decreases until full height is reached. Before the adolescent growth spurt, the two sexes are physically every similar. Afterwards, boys have relatively longer arms and broader shoulders, while girls have relatively broader hips and a lower centre of gravity. The bigger upper-body frame of the adolescent boy allows for the extra upper-body muscle that will develop.

Exercise will neither stunt nor promote growth in terms of height. Instead, it thickens the bones by increasing mineral deposits (Wilmore & Costill, 1994), which is a positive benefit of exercise for children. However, growing bones are sensitive to stress, especially repetitive loading, and so there are injury-risk factors associated with bone growth. This is because bones grow out from a cartilage growth plate at the end of each shaft. These growth plates are called epiphysial plates, and they divide the calcified head of the bone, the epiphysis, and the calcified shaft, the diaphysis. The bone lengthens as cartilage is replaced by bone on the diaphysial border, thus lengthening the shaft. At the same time, cartilage continues to grow on the epiphysial border, so the epiphysial plates retain a constant width of cartilage throughout. Growth ends when the plate eventually calcifies.

‘Too many repetitions of one particular movement involving high loads or high speeds should be avoided with children’

Before full growth is complete, the epiphysial plate is susceptible to injury. For instance, a fracture to the epiphysial plate prior to full growth would be quite a serious injury because it could disrupt bone growth. In addition, anabolic steroid use in children can stunt growth by causing premature calcification of the epiphysial plate (Sharp, 1995).

A more common kind of epiphysial plate injury, and the one coaches must take care not to cause, is called epiphysitis. This is a repetitive-strain injury which occurs when excess loads are placed on the tendons that attach to the epiphysis, causing an inflammatory response. In extreme cases, this type of injury can result in a separation of the epiphysis from the epiphysial plate.

The most common epiphysis, called little leaguer’s elbow, occurs mostly in the States among young baseball pitchers. The excess load comes from throwing a baseball at speeds up to 80mph. In British children, the same kind of injury can occur at the elbows of young tennis players and at the shoulders of young swimmers. Thus, too many repetitions of one particular movement involving high loads or high speeds should be avoided with children. For instance, regular practice sessions involving hundreds of tennis serves can cause problems and should be restricted.

The female knee-cap

The changes in female body shape during the growth spurt also lead to particular injury risks. The hips widen, placing the femur, or thighbone, at a greater inward angle. During running or walking, this increased femur angle leads to greater inward rotation at the knee and foot. This rotation can result in an injury called chrondomalacia patella, which occurs when the kneecap does not run smoothly over the knee-joint and pain is caused at the front of the knee. The right preventive training to avoid chrondomalacia patella would be to strengthen the vastus medialis muscle, which is the inner portion of the quadriceps. This will help counteract the lateral bowing effect of the greater femur angle. Strengthening the lower abdominals, obliques (side of stomach), hip abductor and hip external rotator muscles will help counteract the inward rotations of the knee and stabilise the pelvis. The knee can also be protected by using orthotics to control any over-pronation at the foot.

'Traction injuries' are another type of injury associated with bone growth. Again, they are caused by repetitive loading while the tendon is sensitive to stress. In particular, they are characterised by crescendo pain, ie it gets worse as the activity continues. Traction injuries occur at different sites at different stages of growth. For example, lower-back and iliac pain can occur in late adolescence. Between 10-13 years, it can occur at the heel (known as Sever's disease). Between 12-16 years, it can occur at the knee (Osgood Schlatter's disease) – this is probably the most common of the three. The only cure for these traction injuries is rest. Once the child stops the stressful activity, the tendon will then settle and fuse correctly. Sufficient time must be allowed for the injury to heal completely, otherwise it can recur. Note that poor hamstring and quadriceps flexibility can make the symptoms of Osgood Schlatter's disease much worse, so a useful preventive step for coaches is to include lots of hamstring and quadriceps stretches for children between 12 and 16 years.

Muscles...

As with bones, muscle growth is also uneven. Muscle mass increases steadily until puberty, at which point boys show faster muscle growth. This acceleration is due to a 10-fold increase in serum testosterone, which causes the increased protein synthesis that leads to larger muscle mass. In girls, the increased growth in muscles is less marked. They have growth hormones present pre-puberty and hormonal changes at puberty do not result in high testosterone levels. In both sexes, muscle growth continues post-puberty until around 20 years. At 15, the average boy has 25% relative muscle mass, which increases to 44% at 19. At 15, the average girl has 27% relative muscle mass, which increases to 39% at 19. Muscle mass increases via the mechanism called hypertrophy, which means that the muscle fibres increase in size but not in number. The number of muscle fibres is fixed and won't increase with training.

And fat...

The hormonal changes at puberty also affect body composition in terms of fat. At birth, both boys and girls have a relative fat mass of around 10-12%. Pre-puberty, both girls and boys still have a similar relative fat mass of 16-18%. Post-puberty, girls have high serum oestrogen, which causes the hips to widen and extra fat to be stored in the same area. Consequently, girls' relative fat mass on average increases post-puberty to around 25%. Conversely, the extra muscle increase in boys means that, post-puberty, relative fat mass drops to around 12-14%. However, most athletic females tend to keep body fat at around 18% (Wilmore & Costill 1994). Any lower than 12% body fat for females can be considered unhealthy in terms of maintaining bone density and disrupting hormone levels, which may increase the risk of stress fractures.

The difficulty for most teenage girl athletes, at a time when they start to gain weight, is striking the right balance between keeping in shape, which means about 18% body fat, and not being too paranoid about weight gain and thus not eating enough. Coaches need to make girl athletes aware that eating the right kinds of foods is the way to avoid unwanted weight gain. The right foods include fruits, cereals, wholemeal bread, pasta, rice, potatoes and vegetables, which are all complex carbohydrates and full of nutrients. Protein foods, such as lean meat and fish, which are low in fat, are also necessary for a healthy diet. Foods that need to be avoided are those that are high in fat and simple sugars and empty of nutrients, such as cakes, chocolate, biscuits and sugary drinks.

The basic rule is that eating enough food, especially complex carbohydrates, is essential if athletes are to train consistently and perform well. Carbohydrates as a food group must never be labelled as fattening. Girls must also appreciate that, until 19, they are steadily gaining in muscle and so will naturally be gaining weight anyway. The best way to reassure them that this weight is not fat and that they are at the correct weight is to carry out an accurate percentage body-fat test.

Physical ability

The areas of development discussed above – bone, muscle and fat – are all significant for exercise. This is shown by the fact that a child's ability on a range of physical tests improves with age for both sexes, up to around 18 years. Logically, as children get bigger and develop more muscles, their physical capabilities will improve. Of course, those that grow early will gain an advantage. This may be good in the short term, but potentially disheartening later on. Conversely, late developers will need extra encouragement to play sport or be active, so as to help overcome their initial physical disadvantage. This also means that coaches should remember that children will get bigger, stronger and faster every year, regardless of the training you do with them. Thus, keeping it fun, concentrating on skills and laying foundations for the future, represent the best coaching policy for children. Specialised, advanced training should be saved for later, when the athlete will really need it!

Wilmore and Costill (1994) present data from the President's Council on Physical Fitness and Sports (1986) on various physical tests. The general trend for boys and girls is steady improvement from six to 18 years. However, on the upper-body strength tests, eg flexed-arm hang and pull-ups, boys show marked improvement at puberty. This will coincide with the simultaneous broadening of the shoulders and increased upper-body muscle mass. By contrast, girls show little improvement with age on both these strength tests. The other major difference between girls and boys is shown in the 50m dash, standing long jump and mile-run tests. Girls show little improvement after puberty on these measures, no doubt due to the increased relative fat mass that occurs at this time.

Wilmore and Costill also suggest that girls around puberty are more likely to adopt sedentary lifestyles, which will also negatively affect their abilities. In my opinion, coaches should start to encourage girls post-puberty, at around 15-16 years, to gradually and carefully increase their training, especially their aerobic and strength training. It seems that, post-puberty, the changes that take place in the female body prevent any natural improvement in physical ability from growth alone, so it is at this time that physical training becomes important. This is particularly true for games players rather than runners or swimmers, whose entire training is devoted to physical conditioning anyway. A girl tennis player, for example, should regularly include extra running and strength training to supplement her tennis. Boys, however, seem to have the advantage of continuing to improve naturally until 18. This suggests that advanced physical training can be delayed for them compared to girls.

The purpose of training for young athletes is to provide them with the skills to go on to perform adult training programmes. In particular, games players need to understand that physical training is essential for them to excel, and it must be included in the right form when they are young so it can develop into tough adult training later on. For example, Eastern European coaches have long been strength training young children with bodyweight exercises and light weights. The focus has been on technique and general conditioning – for instance, teaching the power clean with a very light bar. The idea behind this is that, when they are older, they already have the skills in place and a general basic strength, especially in the stomach and lower back, to perform the exercises in a sport-specific strength-training session. The advantage that young swimmers and runners have over young games players is that general conditioning training is usually included in their training programmes from a young age.

Strength training

From the research carried out on the effects of resistance training on children, it would appear that, in general strength improvements are possible. For example, Weltman et al (1986) showed for six- to 11-year-old boys increases in isokinetic strength of 18-37% compared to little improvements for a non-trained control group. This happened after a 14-week training programme. Interestingly, only one boy out of 16 suffered a weight training-related injury and none showed any damage to growth plates, bones or muscles. This suggests that, contrary to popular misconceptions, resistance exercise is quite safe for children. However, I would qualify that statement by saying that poorly performed, unplanned and over-strenuous resistance training is dangerous for children, just as it is for adults. If children are to strength train, they need to be properly taught and undertake a well-controlled, progressive programme. At the same time, their coaches need to remember the points made earlier and ensure that the training programme remains varied and that the joints are not subject to repetitive stresses.

‘Coaches should start to encourage girls post-puberty, at around 15-16 years, to gradually and carefully increase their training, especially their aerobic and strength training’

In adults, researchers have argued that strength gains are partly due to increased neural activity and partly due to hypertrophy. Normally, increased neural activity occurs early in the training programme, with hypertrophy being a more long-term adaptation. However, we cannot assume that the same mechanism exists for children. The fact that they can improve their strength training therefore poses a further question: by what mechanism does the strength improvement occur?

Research into the comparative strength gains from training for different ages by Pfeiffer & Francis (1986) may provide the answer. They trained three groups of males, pre-pubescent, pubescent and post-pubescent. They hypothesised that the pubescent group would show the biggest increases in strength because of the dramatic increase in serum testosterone during that period. This would allow for greater muscle hypertrophy and therefore strength gains. However, while all three groups showed significant improvements, it was the pre-pubescent group that improved significantly more than the other two. This was contrary to the hypothesis, and suggests that the mechanism for strength gains in children is via neural improvement and not hypertrophy. Even though the hormones for hypertrophy are not in place, the pre-pubescent group showed significant strength gains. This is supported by Blimkie (1989) who showed that, after strength training, children increased their motor-unit activation (for more on strength training, see later in this special report).

Aerobic and anaerobic development

Cardiorespiratory function also develops throughout childhood. Lung volume and peak flow rates steadily increase until further growth. For example, maximum ventilation increases from 40 L/min at five years to more than 110 L/min as an adult (Wilmore & Costill, 1994). This means that children have higher respiratory rates than adults, 60 breaths/min compared to 40 breaths/min for the equivalent level of exercise (Sharp 1995). The ventilatory equivalent for oxygen is also higher in children, $VE/VO_2 = 4$ for an eight-year-old compared to 28 for an 18-year-old. This means that children have inferior pulmonary functions to adults.

Cardiovascular function is also different for children. They have a small heart chamber and lower volume than adults. This results in a lower stroke volume than adults, both at rest and during exercise. Chamber size and blood volume gradually increase to adult values with growth. Children compensate for the smaller stroke volume by having higher maximal heart rates than adults. For a mid-teenager, max heart rate could be more than 215 beats/ min compared to a 20-year-old whose max heart rate will be around 195-200 bpm (Sharp, 1995). However, the higher heart rates cannot fully compensate for the lower stroke volume and so children's cardiac output, measured in L/min, is lower than adults (Wilmore & Costill 1994). Children can compensate a little again, as their arterial-venous oxygen difference is greater. This suggests that a greater percentage of the cardiac output goes to the working muscles than in adults (Wilmore & Costill 1994).

Because of the fact that lung and heart capacity increase with age, one would expect aerobic capacity to increase accordingly. This is true in absolute terms. VO_2max, measured in L/kg/min, increases from six to 18 years for boys and from six to 14 for girls. However, when VO_2max is normalised by body weight, children have a cardiorespiratory system for effective aerobic exercise. This is demonstrated by the fact that children can run quite well compared to adults. Indeed 10-year-olds have completed marathons in very respectable times.

For the young athlete, running endurance performance is not limited by an inferior VO_2max, expressed in L/kg/min. In fact, young prepubescent girls have an advantage before their relative body fat increases. Instead, endurance performance is limited by poor running economy. This means that for a given pace a child requires a higher oxygen consumption than an adult. Children have shorter limbs and a smaller muscle mass, resulting in a lower mechanical power. They have disproportionately long legs, meaning that they are biomechanically out of balance and potentially less coordinated. In addition they have a greater surface area to mass ratio. All these factors reduce biomechanical efficiency. Physiologically, children have inferior cooling mechanisms, due to low blood volume and high skin temperature. They also expend more energy per kilogram of body weight. Children have a higher VE/VO_2 ratio due to their inferior lung function and they rely more on fat metabolism because of a lack of muscle glycogen and glycolytic enzymes. All these factors reduce physiological efficiency. Combined, these biomechanical and physiological limitations lead to a reduced running economy, though this seems to improve with age from eight to 20 years (Wilmore & Costill, 1994).

Although they are biomechanically and physiologically inefficient, children rely heavily on aerobic metabolism for exercise. Sharp (1995) describes them as aerobic animals. The anaerobic capacity for both boys and girls increases with age, but is not fully developed until around 20 years. The main reason for this is probably the lack of muscle mass. However, children also have less glycogen stored per gram of muscle along with less phosphofructokinase (PFK), an important glycolytic enzyme. They also have lower creatine phosphate stores per gram of muscle (Sharp, 1995). Children are thus unable to generate the low blood pH or high blood lactate values that are associated with anaerobic work (Malina, 1991). This means that the natural fatigue mechanisms from intense work that adults possess do not exist with children. This, along with the fact that they tend to overheat more than adults, are the major risk factors that coaches need to be aware of when training young athletes at high intensities. For instance, on sprint interval training, while they may appear to be able to keep going in that they have not developed high acidosis, their muscles will still be fatigued and they may be hot if it is warm weather or indoors.

Aerobic training

As children are naturally more aerobic, it would be useful to know if aerobic capacity is trainable in them. Unfortunately, few studies have shown that aerobic capacity in children improves with aerobic training. However, Rowland (1992) argued that no study has been done that included all the following criteria: at least 12 weeks' training, three times a week training, heart rate at least 160 bpm for at least 20 minutes, and using a large group plus matched controls. This would be the equivalent of an adult aerobic training programme in a well-controlled study. Rowland found in his study of children, that when adult-type training in terms of intensity was performed, VO_2max improved between 7 and 26%. This suggests that children can improve their aerobic fitness from a training programme of adult-like intensity.

The argument for doing this is probably valid. Sharp (1995) shows that, because of lower lactate production, the anaerobic threshold for children is normally at pulse rates around 165-170 bpm, similar to that of trained endurance adults. With sedentary adults, the anaerobic threshold will vary from 120-150 bpm. Thus the optimal heart-rate training stimulus may be relatively high for sedentary children than for sedentary adults. Other evidence supporting the high-intensity stimulus theory is the fact that activity levels in children are not related to VO_2max (Rowland 1992). While children may not be as active now as they were in the past, they are still as aerobically fit (Armstrong & Welsman, 1994). This shows that general activity does not provide a training stimulus, and suggests that children have a natural fitness. Thus, to improve on their natural fitness, a reasonably tough training programme is required.

'The most important areas of training for children are strength, speed, coordination, sport-specific skills, and agility'

Conclusions

It's useful for coaches to know that aerobic capacity is probably trainable in children with a sufficient training stimulus. This makes aerobic training worthwhile, since it will improve their performance. However, the training effect will not be as great as is possible with adults because the lower stroke volume in children prior to full growth will limit the potential cardiac output increases with training. In addition, until after puberty, poor running economy limits running endurance. Thus, as before, it is probably best to wait until the young athlete reaches adolescence before starting tough aerobic training, as this is the age when the athlete will truly benefit. Tough anaerobic training is of even more limited use for children since they possess little anaerobic capacity.

In my opinion, the most important areas of training for children are strength, speed, coordination, sport-specific skills, and agility. These are areas where improvements can be made through enhanced neuromuscular recruitment, laying down the skills for adulthood. As the nervous system develops, it seems that the potential for improvement in skills is the greatest. Training for aerobic and anaerobic endurance can be improved from adolescence when the body has reached its natural capacity and responses from this kind of metabolic training are greatest.

Raphael Brandon

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Technical proficiency is one thing, but those who train the young ignore these basics at their peril – a famous coach explains

The fundamentals of athletics techniques were established almost a century ago; since then, there has been a gradual refinement of these basics, much of it by trial and error.

The beefy Scots agricultural labourers who heaved the 16lb shot to around 15 metres a century or more ago knew well that the aim of the 'shift' was to give the shot initial velocity; they knew, too, that any speed gained in the shift was worthless if they didn't achieve a strong, balanced throwing position.

Similarly, 19th-century high jumpers were well aware of the advantages of a flat lay-out over the crossbar. Indeed, the great Scottish all-rounder Donald Dinnie reported back on what seems to have been a primitive 'straddle' from a US tour in the 1870s. And it is clear from the literature that Victorian jumpers clearly understood the supreme importance of an accurate, vertical take-off.

Thus, by the mid-1920s the American Clinton Larson had cleared over 2m, using a fast approach and a back lay-out 'scissors' technique. The curved Fosbury-type approach run had already been in use since the mid 1890s by 'Eastern cut-off' jumpers and only rule limitations (on 'diving') and the unforgiving nature of the landing areas delayed the appearance of what was to become the Fosbury Flop more than 40 years later.

If we consider hurdling we can see that the hurdlers in early

Olympics were using similar techniques to those used by modern athletes. What they lacked were firm take-offs and even surfaces (AAA championships were held on grass into the 1920s) and, of course, they devoted much less time to their training than their modern counterparts. A viewing of the 1936 Olympic 110m hurdles final displays the relatively ragged techniques of the period – a clumsiness magnified by soft cinder surfaces.

From our modern vantage point it is difficult to envisage any major changes in track and field techniques in future, unless there is a substantial change in the rules – such as allowing a two-footed take-off in the high jump. Even increasing the circle size in throws would lead only to a modification of existing techniques, since the basic throwing position would remain the same.

However, our increasing sophistication of technique has brought about its own problems; most notably, it has tended to divert coaches away from teaching basic skills to young athletes.

So, for example, as a national coach, I might be asked to teach a ‘hitch kick’ to a girl who could barely leap 4m and who lacked the ability to hit a take-off board accurately in a good position; or I might be expected to introduce the ‘O’Brien’ technique to a lad who could barely launch the shot beyond his left foot.

The language of priorities

Aneurin Bevan said that ‘socialism is the language of priorities’; so, too, is coaching, which involves much more than the advanced technical knowledge of the coach. A coach who is working successfully with a shot-putter launching the 16lb ball to over 20m may have little idea of how to introduce the event to 12-year-old novices. This is because he has given little thought to the essential technical priorities or presentation methods at this level. Thus, he will often use the standard shot and attempt a backward shift across the circle or rear-facing standing puts – approaches that are doomed to failure.

So what might the coaching priorities be in such a situation? I would list them as follows:

1. To use light shots (or stones) which children should be able to launch to respectable distances;
2. To use simple standing puts, preferably frontal ones;
3. To secure the largest possible number of puts in the time available.

The aim of the coach must always be to work from success – from things that children can actually do. Anyone can put a light shot (elbow out, left side high) from a kneeling or standing frontal position with minimum technical errors, which guarantees instant success and rapid improvement. All that needs to be done in the first session is to make small increases in movement range and the shot will automatically travel further. Mission accomplished!

‘The aim of the coach must always be to work from success – from things that children can actually do’

The priorities in such sessions with groups of children are quite different from those applying to mature throwers. The first aim is to allow the novices to experience the sheer enjoyment of launching a shot a fair distance into space; the second is to establish some essential basic techniques, such as hold, elbow position and driving up over a high left side. It will take many repetitions before there is any point in trying to go further.

Warriors with vaulting poles

Sports like gymnastics have always taken this conservative approach to coaching, driven as much by safety requirements as common sense. Athletics, alas, has not always followed suit and thus, in my local schools athletics league, I see under-15s arriving at meets like Samurai warriors, bearing fibreglass vaulting poles that are about as much use to them as lengths of steel scaffolding! When competition starts, none of them has the slightest idea how to hold or plant poles which are, in any case, invariably 10-20kg too stiff for them.

In a sense being ‘technically correct’ is the easy part of the coaching equation. Unless this information can be transformed into something practical, by passing through the sieve of ‘contextual experience’, it is virtually worthless. Knowledge – about anything – can be divided broadly into four categories:

1. Basic information;
2. Knowledge;
3. Applied knowledge;
4. Knowledge in reflection.

The coaching world is drowning in basic information and knowledge – the type that describes and analyses training techniques and methods; indeed this type of material accounts for much of the available technical literature.

What we lack are the fruits of applied knowledge, when the coach has deployed this basic information in practical situations and derived something workable from that experience. Even rarer is knowledge in reflection, when the coach has reflected upon the practical application of his knowledge and come up with fresh, reworked ideas.

‘The coaching world is drowning in basic information and knowledge’

Now, such categorisation of knowledge might appear over-academic, and some coaches might argue that good coaching is a totality, encompassing all four categories. I would not argue with this, except to say that the descriptive, ‘technically correct’ approach has tended to hold sway, often devaluing the products of practical experience. Certainly, this was one of the first effects of the development of formal coach education in the second half of the 20th century. Thus, untrained coaches who had coached Powderhall sprint champions did not secure the same respect as less successful men who were able to repeat the conventional technical wisdom, and this led to the impoverishment of the literature and of coach education.

The practical approach is, however, alive and well in some specialisms, notably decathlon, by its nature an event of half-skills. Even at Olympic level we see decathletes using short approaches, with the javelin already in the withdrawn position; simple ‘sail-type’ jumps in the long jump; and surprisingly basic hurdle techniques. Although these men represent the world’s physical elite, their techniques are often surprisingly ordinary. Why? Because they don’t have the time to develop sophisticated technical models and therefore opt for less ambitious techniques that confer competence rather than brilliance.

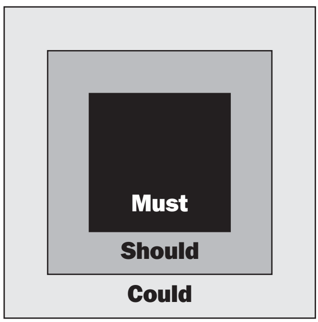
Deciding what the core skills are

These decathletes have lessons for all of us – and this takes us back to the importance of establishing the fundamentals of technique in young people. We know, for example, that the main aim for eight to 11-year-olds is to establish the raw skills of jumping, kicking and throwing, with no need to spend much time on specifics. The 12-15 age group, however, need to master basic technical models – the core skills without which fitness and tactical understanding would have little on which to rest. Anyone watching Korean hockey players, for example, can see that their subtle skills have been established in youth by frequent repetition; it is difficult to graft on movements of such subtlety in adult life.

The problem in athletics lies in deciding exactly what the core skills are and how to present and establish them. It is disappointing to attend an under-15 girls' club discus competition and see it won with a distance of less than 20m, with the last-placer throwing around half that distance. A couple of sessions with any group of 14-year-olds will produce someone who can throw around 20m – some from a standing position.

The same is true of under-15 boys in triple jump, where it is common to see lads landing on the balls of their feet, producing the classic long hop recovery step techniques. Half a dozen training jumps could resolve this problem, yet clearly those jumps have not occurred – and probably never will.

The essence of what I am saying is distilled in the illustration (right), where the 'must' material is absolutely essential, 'should' can be left alone for a while and 'could' is rarely reached, except by mature athletes.



The problem is in deciding what goes in the 'must' box and how to present it effectively. Let me illustrate this by presenting, for example, a coach or teacher taking a group of six children aged 10-11 for high jump. He does not use the high jump landing bed, for the bed itself represents a 'personal best' for many children of this age. Instead he uses either side of the long jump pit or puts down landing mats in the high jump area. First, a take-off zone should be marked, using talcum powder, then a standard three-stride approach mark which can later be adjusted to the needs of differing children.

What is the purpose of the take-off zone? It is to ensure that the jumper's high point is close to the centre of the crossbar, at its lowest point. What is the point of a straight three-stride approach? Simply to enable a 'scissors' technique from an accurate approach. Without establishing these basic elements of a consistent approach, taking off from the same point, we can do very little.

The myth of annual progression

Such simple prescriptive methods enable children to understand what high jumping is about, whether they are pursuing it in a club context or as part of the school curriculum.

Understanding provides the basis for intelligent practice, away from coach or teacher. And for practice to work there must be lots of it. Anyone who has ever taken up a sport like tennis knows that it takes some time before it is possible, even with coaching, to sustain a collaborative five-stroke rally.

Physical education has as its central premise the idea that children should be guided through a range of sports by someone who is not a specialist in most of them. Underlying this premise is the belief that each child will find a sport in which he or she has some ability.

However, experience tells us that this is rarely so. What actually happens is that physically gifted children dominate almost every activity, while those at the other end of the physical spectrum encounter little but failure. This is because achieving competence in any sport invariably takes time – time which is not normally available within the PE curriculum.

While practice does not make perfect, it does make permanent. Work on core skills needs a great deal of repetition, in the process of which the percentage of inferior efforts gradually diminishes, before competence is achieved. And without competence there is little hope of pleasure, which is, after all, what sport is all about.

Another problem with sport in the curricular context is the myth of inevitable annual technical progression. Thus we have syllabi that outline a certain level of technical development at age 12, another at 13, and so on. Now, while it is true that a girl of 13 is fairly likely to be able to throw a javelin further than she could at 12, her performance will not necessarily be technically superior.

‘Technical skills achieved year on year within curricular time are likely to be fairly static, simply because of lack of repetition’

Imagine that you were taken to a golf driving range and coached through 50-odd balls, then did no golf for a year. On returning to the range a year later, would you really expect to be any more technically proficient. Of course not! If, on the other hand, you had joined a golf club and hit a thousand balls during that year, you would probably be more technically proficient, even without coaching. To return to our school example, technical skills achieved year on year within curricular time are likely to be fairly static, simply because of lack of repetition.

Because performance outcomes in PE are never tested, we have little means of knowing what level of technique a child has achieved as a direct product of his school experience. And, alas, the empirical evidence offers little in the way of encouragement, since my experience with A-level PE students shows that few of them can claim to master even the most rudimentary athletics technique. It is not, therefore, a question of whether or not they can perform an adequate triple jump from a run, but whether or not they can even perform a standing triple jump.

Curricular athletics teaching, therefore,appears to be an empty box, and the coaching of young athletes at club level is little better. This does not mean there may not be oases of good practice in schools and clubs – only that they are not the norm.

What is most troubling about out failure to address curricular and induction issues over the past half century has been the unwillingness of physical educationists to admit that the emperor has no clothes: that the majority of children leave school without basic competence in any sport – the equivalent of a five-stroke rally in tennis, a standing shot put, or an accurate 10-yard pass in football. No child enjoys lack of competence and, without enjoyment, there is no prospect of children continuing in sport beyond school.

Unless this issue is addressed, there is little prospect of increased adult participation in sport, for the foundations have not been laid. We must give our children roots to grow and wings to fly.

Tom McNab

A youth rugby coach explains he uses psychology to raise his players' game

In professional sport, coaches are under intense pressure to perform. For instance, in the final game of the English domestic Rugby Union season in 2003, Saracens played Leicester, with the winner offered a chance to play in the European Cup the following season, an opportunity worth about £250,000 in extra gate receipts and sponsorship money for the club. Saracens lost, and the entire coaching staff was sacked, having been in place for just one season.

Coaches have a tendency to tackle poor performance by increasing training load[1], which may actually exacerbate the problem rather than solving it. Underperformance can be caused by a number of factors, including injury, fatigue, loss of confidence or motivation, relationship problems (within or outside the team), and other external stressors, such as exams, career or financial problems.

Two different athletes given the same workload and intensity may respond quite differently to the stimulus. What may be optimal for one may be too much for the other. The same could be said for an individual who responds differently to the same workload in two different training cycles. The key factor here may not be the workload, but something else going on in that athlete's life.

Rugby Union is a sport where the physical demands are high through exertion and from contact. The English domestic season lasts from late August to early May. Keeping players in a physical state that allows for peak performance week after week is difficult[2]; ensuring their physical and mental recovery is even more challenging.

In my role as conditioning coach at London Welsh Rugby Football Club, I have had the opportunity to measure and assess the amount of fatigue associated with training and lifestyles and to try to reduce its impact on the players' performance.

Recovery may be most important for youth players as 30% of team sport players aged 16-20 suffer from staleness[3]. Such athletes face often-conflicting pressures from teachers, parents, coaches, peers, relationships, work and training, which can lead to staleness, burnout and injury[4].

What do we mean by these terms? Short-term overtraining, known as 'overreaching', can be seen as a normal part of athletic training and must be distinguished from long-term overtraining that can lead to burnout, staleness, or 'overtraining syndrome'[5]. Staleness can be distinguished from burnout by the athlete's motivation to train; while the symptoms may be similar, a stale athlete is still motivated to train and a burned-out athlete is not[6].

'Unexplained underperformance syndrome'

Because of the many potential causes of poor performance, overtraining syndrome (OTS) has recently been redefined as the 'unexplained underperformance syndrome' (UPS). It can be distinguished from overreaching by the fact that symptoms do not diminish after two weeks of rest[7]. However, these terms will be used interchangeably in this article because of their usage in research.

Preventing UPS calls for a careful balance of training stimulus and recovery – the latter defined as 'a well-planned activity that matches the situational needs of an athlete in rest and results in regaining an optimal performance state'[8]. However, training is much easier to manipulate and measure than recovery because of the difficulty of accurately recording and quantifying the latter state.

Nevertheless, having an accurate measure of recovery may be useful to a coach because he or she can then identify any problems that may be preventing the athlete from achieving peak performance. Any such measure must also be affordable and easy to use in order to work in the coaching environment. This may be especially true when working with youth athletes, where budgets tend to be more restricted.

What measures have been used to date – and how effective have they been? Heart rates which are elevated in the morning and reduced during submaximal exercise have been cited as indications of OTS[9-13]. But this has not been found in all studies, including those on judoka[14], cyclists and triathletes[15], swimmers[16,17] and runners[17,18,19]. In one study, individual differences in resting heart rate were found in overtrained runners, calling into question the reliability of one marker as an accurate measurement of OTS[20].

This particular marker is also dubious because resting morning heart rates are known to be reduced by a good night's sleep[21], and none of the studies that noted elevated resting heart rate in overtrained athletes took sleep into account as a factor.

Markers of excessive training

Usitalo et al could not find a universal pattern of physiological responses to excessive training, which appears to be the main problem at present: no one physiological marker is reliable for all athletes, while relying on a combination of markers may not accurately distinguish between overreaching and OTS. The only consistent factor is a decline in the athlete's performance[22].

Psychological measures have been proven to be as effective as physical measures in diagnosing 'training stresses'[23]. Could these also be useful for predicting and diagnosing OTS? One commonly-cited tool is the Profile of Mood States questionnaire (POMS), which, as its name suggests, measures moods. However, moods are highly contagious among athletes, with highly motivated athletes and women seeming to be at higher risk. Thus, this may be a less useful tool in a team environment and is also considered unreliable as an indicator of staleness[24].

A more recent psychological tool is the Rest-Q – the

Recovery-Stress questionnaire for athletes, devised by Kellmann and Kallus[25], which asks questions about the athlete's current state of recovery and stress. This tool attempts to integrate the useful parts of the POMS into a more functional assessment of an athlete's current training status. It uses 19 scales relevant in the recovery process, such as general stress, self-efficacy and emotional exhaustion, and has been demonstrably effective in monitoring training dosages in elite training camps[26,27].

As part of my work with London Welsh RFC, I have been using the Rest-Q for the last two seasons to monitor levels of recovery and stress in the academy players, in conjunction with their physical fitness. My aim was to see if the Rest-Q, administered throughout the season at intervals of 6-8 weeks, would be useful in preventing underperformance in a semi-professional, part-time training environment, similar to many within the UK.

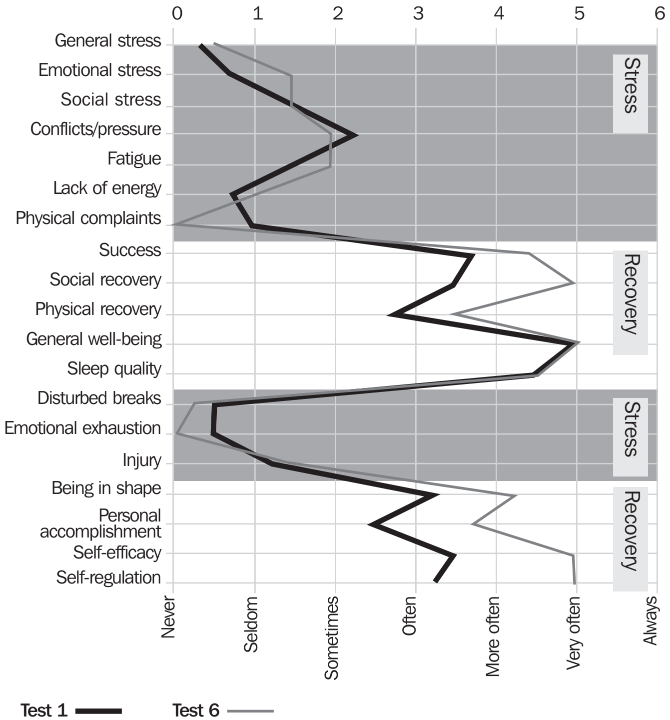
On the recommendation of the tool's author, we measured physical fitness at the same time as measuring psychological wellbeing with the Rest-Q; if a player was in a bad physical state, we wanted to know whether this was due to a drop in fitness or other pressures affecting his performance.

When we looked back on the first season's scores, we saw remarkable differences between those players who had consistent performances and went on to representative honours at age-group level and those whose form slumped, or who suffered from burnout or UPS.

At the end of the season I performed a statistical analysis of the Rest-Q scores on the academy as a whole, looking at stress and recovery scores, injury prevalence, physical fitness and playing performance. This did not produce any significant results.

I then divided the players into four main categories: players who performed well; those who suffered from burnout; those who suffered from performance slumps; and those whose fitness levels and performances were consistent throughout the season, and who didn't get injured. By homing in on individual

Figure 1: player A's Rest-Q scores at both ends of the season

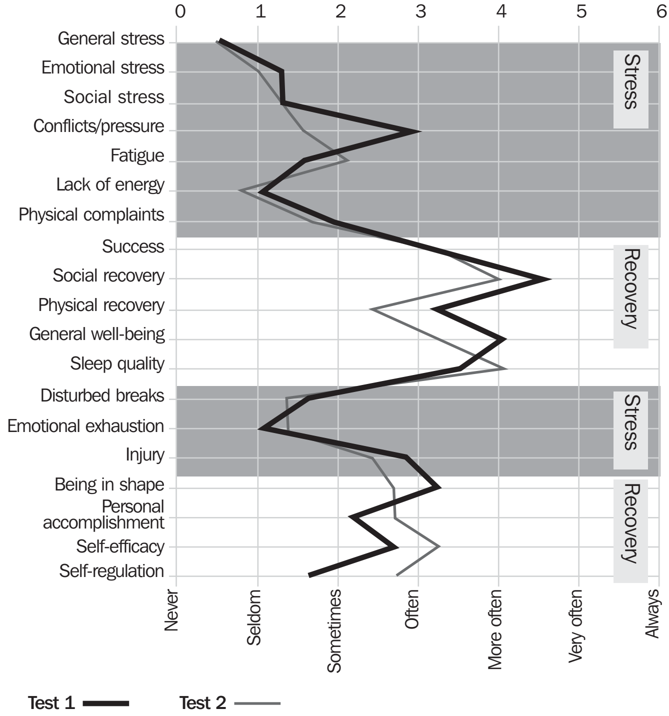


players in more detail, we hoped to see trends that were common to the groups. Two of the individuals are presented as case histories here: Player A, who performed better than expected, and Player D who suffered from burnout.

Player A's graph (figure 1, above) shows high levels of recovery and low levels of stress at test 1 and at test 6 (pre-season and end of season). He also shows higher levels of success, social recovery, physical recovery, personal accomplishment, self-efficacy and self-regulation at test 6 than at test 1. He was selected for the Wales under-19 squad for the Six Nations tournament.

This player lived at home, and his dad attended all the training sessions and matches throughout the season. Social

Figure 2: player D's Rest-Q scores in two pre-season tests four weeks apart



support has been shown to contribute to health and wellbeing by reducing exposure to stress and enhancing coping efforts(28). He was studying at school, but did not work to earn money. This may have been a significant reason for his continued success, enabling him to concentrate on his rugby and recover at home.

Player D's graph (figure 2, above) shows minor differences during the two pre-season tests, with test 2 carried out four weeks after test 1 and four weeks before he dropped out of the academy. Social and physical recovery and general wellbeing score lower in the second test, but self-efficacy and self-regulation score higher. In a follow-up conversation this player expressed dissatisfaction with his own performance and said he had been consistently under pressure at work as an apprentice. He cited his early morning starts as a main reason for not being able to recover from training the previous evening. He lived with his parents and had few household chores and little homework to contend with, but his parents did not show any overt signs of support for him within the rugby environment. This may have been a significant factor in his decision to drop out from the sport, as people who have weak social ties, including those with their immediate family, have been shown to have weaker health than those with strong social ties[29].

Compared with previous research using case studies[25,26], this study showed the importance of external influences on each player. For example, Kellmann used the Rest-Q to highlight the relationship between an increase in training dose and increased stress and decreased recovery in rowers. But as these athletes were attending a full-time training camp, external influences would have been minimised.

The two major adverse external influences my research uncovered, were living away from home and playing for additional teams. The effects of living away from home could have been due to missing the structure and support associated with both the school and home environments[29,30,31].

The influence of non-athletes in the university environment, combined with a new-found freedom and lack of accountability for the first few months, could have created a new 'perceived social norm', in which training and good dietary and sleep habits were of secondary importance to fitting in with everyone else.

Dishman et al[29] discovered five main indicators of adherence to training programmes: training partners, social support, time and opportunities, self-efficacy, and perceived vulnerability. While players at university had plenty of time and opportunities to train and play, as well as access to training partners, their recovery habits were poor, with too little quality rest, inadequate diet and a poor support structure. This led to inconsistent or deteriorating performances that could result in burnout.

Advantages of living at home

Players living at home, either studying for A-levels or in full-time employment, had less time and opportunity to train, but generally had better social support and recovery habits, which led to more consistent playing patterns throughout the season. Despite their work pressures, players living at home tended to have better strategies for coping with stress than those at university, who had poorer social support and inadequate recovery strategies. These latter players appeared to be underrecovered rather than overtrained.

'While the Rest-Q did not highlight the causes of inadequate performance, it did pick out players who had poor recovery routines and those who were suffering from stress'

Playing for additional teams put the athletes under physical and mental pressure. The inability to recover properly between one match and the next led to a decline in fitness and an inability to shake off niggling injuries, while the inability to say 'no' to coaches at university, school or club led to an increase in stress, which has been shown to affect overall performance[32].

While the Rest-Q did not highlight the causes of inadequate performance, it did pick out players who had poor recovery routines and those who were suffering from stress. These two factors were not always concurrent, reinforcing the view that they are different parts of a process leading to underperformance[33]. This enabled the coach to have more in-depth conversations with the players and to a greater understanding of the motivation and habits of each player.

However, the use of the Rest-Q at intervals of six to eight weeks did sometimes lead to players being overlooked when symptoms of overreaching appeared between tests, while the logistics of testing a total of 81 players, inputting and analysing the data, meant that a quick response was not always available to individual players. Also, the exercise only picked out those players whose profiles changed significantly between tests, which meant that some players on the road to UPS were overlooked. The Rest-Q is not a substitute for good communication between the coach and his individual players. But we have found it to be very useful for analysing each player and feeding back information which might be affecting performances as quickly as possible.

With one season of players' histories available to us and a greater understanding of the areas to be monitored, comparisons have been more accurate in the current season. After identifying the main areas of concern, several changes have been made. I as conditioning coach have taken responsibility for educating players, parents and coaching staff on the need for a balance between training and recovery. An eight-week training macrocycle has been put in place, comprising two four-week training blocks, with the last week of each block being a recovery week.

Testing, including the use of the Rest-Q, takes place on completion of the second recovery week. Players who have shown significant changes in their Rest-Q scores will be recommended to see their doctors to eliminate the possibility of clinical illness. Many of the symptoms of UPS are similar to those of depression[34], so it is important for those doctors to have some knowledge of the syndrome. One case of UPS was diagnosed, and the player in question was rested for four weeks, then eased back into training. He is currently playing well.

A consensus has been reached among the coaching staff that new university students need more support than they received last season, particularly for improving their self-regulation, which may have been largely dependent on parental support previously.

Meetings are regularly held with all players to deal with injuries, selection issues and other problems, an approach which has been shown to be useful in alleviating stress[34]. In the previous season, players who got injured did not always continue their rehabilitation, or stopped attending training sessions for five to six weeks.

The coaching staff have realised that they are as important as physiotherapists to injured players and now play a more active role in communicating with them. With the coaches now considerably more aware of the importance of recovery and the risks of the stress some of the players face, it is our hope that the incidence of underperformance and burnout will be greatly reduced.

James Marshall

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This is what science says is the most effective endurance training for kids...

The science of developmental physiology can supply answers to certain important questions regarding the training of children. One such question is: should children perform adult-type endurance training in reduced quantities, or should they be performing a different type of training that is tailored to their physiology? Science suggests the latter is true and that the type and intensity of training that is most effective for developing endurance in the young will be different from that used by adults. In this article I want to discuss some of the evidence that points to this.

The average adult model for endurance training involves an intensity of 75% of max heart rate maintained for 20-30 minutes. If this is performed three to five times a week, then the average adult can expect a 25% improvement in VO_2max. This improvement in fitness is caused by both an increase in stroke volume and an improvement in O_2 respiration and metabolism in the working muscles due to increased capillaries, mitochondria and enzyme activity.

Lower in children

Several training studies have been carried out on children to find out what effect a cardiovascular (CV) training programme will have on fitness levels. In general, the research shows that if children follow a three to five times a week routine of at least 20 minutes' continuous activity for 12 weeks, then improvements in VO_2max of 7-26% are possible. On average, though, and the results of some of the better controlled experiments support this, a child can expect a 10% improvement in VO_2max after following an 'adult-like' CV training programme. The consensus from the research is that children can improve their aerobic fitness but not to the same degree as adults, when following a similar training programme.

Why is this so? Some scientists have hypothesised that the reason for this diminished training effect in children is that a 'hormonal trigger' exists which limits CV trainability until puberty. It seems reasonable that until growth hormone levels, such as testosterone, rise, then increasing the size of the heart through endurance training may be limited, just as increasing the size of the muscles through strength training is limited until post-puberty. A child's heart is smaller than an adult's and does not achieve its natural full size until full height is reached. Thus stroke volume, which is the amount of blood the heart can pump with one beat, is lower in children and it may be that any further improvements in VO_2max are limited by this.

Further evidence

Evidence to support the theory that immaturity limits trainability can be garnered from observations of elite endurance-trained children. It is rare that an elite child athlete has a VO_2max greater than 65ml/kg/min compared to elite adults who can achieve VO_2max scores above 80ml/kg/min. This suggests that even with well-trained individuals there is a ceiling on possible improvements. In addition, longitudinal studies analysing VO_2max development in young endurance-trained athletes have shown that they benefit from a jump in VO_2max levels around puberty of sometimes as much as 10 points. This observed hike in fitness levels supports the idea that puberty is a crucial time for the trainability of VO_2max.

Another factor that could explain the diminished training effect in children is that the pre-training status of the average child is higher than the pre-training status of the average adult. Children have VO_2max scores of around 40-50ml/kg/min whereas the untrained adult scores in the 35-40ml/kg/min range. Children are naturally fit and will remain fit independent of their activity levels until 14 years in girls and 18 years in boys. Thereafter, CV training is required to maintain fitness. Thus it seems logical that if children have higher fitness levels than adults to start with, they will gain fewer benefits when following the average 'adult' CV training plan.

Train at a higher level?

Research has proved that for adults who have been training consistently for a long period and whose fitness levels are already high, the basic level of endurance training (3 x week, 20 minutes, HR 75% max) will not bring about any further improvements. This is why elite endurance athletes build up to training 10-14 times a week and use high-intensity interval training at maximal heart rates alongside the moderate-intensity continuous training. By extension, the same may be true for children and that to significantly improve their already good 'natural' fitness they may need to train to a higher level than the average adult model prescribes.

'It seems logical that if children have higher fitness levels than adults to start with, they will gain fewer benefits when following the average "adult" CV training plan'

Related to this idea that children may need to train quite hard to improve their VO_2max is a third factor which may explain the reduced trainability of children observed in the research. This is the fact that children have higher anaerobic thresholds (AT) than adults and therefore may require higher intensities of cardiovascular training for optimum benefits. It is accepted that training at one's AT when performing continuous training is potentially the best intensity for fitness benefits because it is the maximum intensity that one can maintain before lactate starts to accumulate. The average adult will have an AT around 75% of max heart rate, but research has shown that children's AT is around 85% of max heart rate, suggesting that higher intensity training will be more appropriate for children. If we assume that a child's maximum heart rate is 205 bpm, then the optimum training heart rate for continuous CV training will be 174 bpm (205 x 0.85) which is considerably higher than the rate normally recommended for the average adult.

Children burn more fat

One of the major physiological differences between adults and children is that between aerobic and anaerobic metabolism. Children have limited anaerobic glycolysis capabilities until post-puberty because they have much lower glycolytic enzyme activity.

For example, Eriksson et al (1973) in their famous study showed that 11- to 13-year-old boys have at least half the PFK enzyme activity of an adult. This means that children cannot produce as much energy through anaerobic glycolysis and rely more on aerobic metabolism. To aid this, children have greater aerobic enzyme activity than adults and burn a greater proportion of fats during aerobic exercise.

Because children are naturally aerobic and are good fat-burners, it thus makes sense that higher intensity training which taxes the glycolitic system, rather than the fatty acid system, would be more useful, since this is the physiological area in which children are limited.

Eriksson et al showed that high-intensity endurance training can significantly increase the PFK enzyme activity and the peak lactate response to exercise in children, which suggests that the anaerobic glycolysis function can improve with training. Arguably, improvements in aerobic capacity rely on the development of anaerobic metabolism, since anaerobic glycolysis is the starting point for aerobic glycolysis. Glycogen is first broken down into pyruvate via anaerobic glycolysis and then, with sufficient oxygen present, the pyruvate enters the Kreb's cycle to be burned in the mitochondria. In this way, anaerobic and aerobic metabolism are inextricably linked and the aerobic metabolism of glycogen, which is the most efficient and important fuel for endurance performance, cannot improve until anaerobic glycolysis develops. To support this argument, research shows that in pre-pubertal children anaerobic power, measured on the Wingate test, and aerobic power, measured with a VO_2max test, are highly correlated. This suggests that, at a young age, the two systems are related and possibly dependent on each other.

Conclusion

In simple terms, all this physiological discussion relates to the fact that the most effective endurance training for children will involve high heart rates achieving at least AT. The goal should be to challenge the glycogen-burning capabilities and recruit the Type IIa fibres. It may also be possible that, pre-puberty, one could improve endurance performance by using only one short burst of anaerobic-type training, although it is impossible to say whether this type of training alone would be sufficient.

The condensed version is this: on average, pre-puberty children can improve their VO_2max but not as much as adults can, after following a normal CV training plan (3-5 x week, 75% max HR, 20 minutes). After puberty it seems that greater improvements in VO_2max are possible and this may be related to sexual maturation or simply the child's limited cardiac output. It is also possible that children benefit less from adult-type CV training because they have higher initial fitness. Children, pre-puberty, seem to be naturally quite fit, and so CV training at this stage is not necessarily a priority. During and after puberty, when the benefits from training are greater, may be the most appropriate time to start serious endurance training. One could argue that anaerobic short-burst interval training may be more beneficial for pre-pubertal children, as they can benefit greatly from this type of training via improvements in anaerobic glycolysis, which is limited at a young age. The most effective kind of endurance training for children will be high-intensity continuous or interval training, where heart rates reach AT and above. It is likely that children have an AT of around 85% of max HR and, for elite young endurance athletes, it may be higher still.

Raphael Brandon

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...and this is what science says is the most effective strength training for kids

In the last article I discussed endurance training for children. In this one I want to talk about the science behind strength training for young children.

As children grow in size and develop muscle mass, they also develop increased strength. These strength improvements are independent of training. In other words, children grow bigger and stronger until full maturity. For example, the average six-year-old boy can do five press-ups, a 12-year-old boy can do 15 press-ups and 18-year-olds can do 25 press-ups. In contrast, the average six-year-old girl can do five press-ups, a 12-year-old girl can do 12 press-ups and an 18-year-old girl can still only do 12 press-ups. This is the usual pattern of development for boys and girls; they are both similar as young children, but post-puberty the boys' strength development accelerates while the girls reach a plateau. This diversity between sexes is mostly due to the hormonal changes which occur at puberty. Testosterone, which increases rapidly in boys, programmes extra upper-body bone growth and muscular hypertrophy. In contrast, oestrogen, which increases in girls, programmes extra pelvic-bone development and increased body-fat storage. These changes mean that boys' strength will increase naturally until 18-20 years, whereas girls' strength, especially in the upper limbs, is unlikely to improve naturally beyond 14 years.

Fibre 'insulation'

Not all the natural development of strength is due to gains in muscle bulk. Strength also improves because of maturation of the neural systems. One of the major changes that occurs throughout childhood is the myelination of the nerve fibres. Myelination, in lay terms, is the 'insulation' of the fibres to allow faster conductivity of the electrical impulses. Full myelination is completed in adolescence, and so until then coordination and reactions will be limited.

There is some evidence to suggest that muscular recruitment also improves with age; adults are able to recruit more motor units when performing maximum efforts, compared to children. In addition, the coordination of synergistic and antagonistic muscles develops with age. For example, a child performing a press-up often has difficulty maintaining a straight back, stable pelvis and stable shoulder position during the up-and-down movement.

This is the reason why children often perform press-ups with their bums sticking up, shoulders rounded and hands in front of their heads. It is not until all the stabilising muscle groups are developed and become correctly coordinated with the prime movers that good form can be achieved on bodyweight and free-weight exercises such as the press-up.

Strength training can work

Strength naturally increases with age because of body growth and development of the neuromuscular system, but can strength in children be increased through training? The majority of the existing research provides convincing evidence that it can. One of the most important studies investigating the strength-training potential of young children was completed by Ramsay et al in 1990. They studied the effects of a 20-week strength-training programme on 9- to 11-year-old boys – specifically, elbow-flexion and knee-extension strength. The training programme comprised sessions of three times a week, three to five sets per exercise, performed at 8-12 repetition maximum (RM) intensity. This refers to weights that can only be performed eight to 12 times with good form. Therefore, the training programme these boys undertook involved sufficient duration, intensity, volume and frequency to ensure that it would be an effective training dose.

Ramsay et al found that elbow-flexion force increased by 37% and knee-extension force increased by 21% in comparison with a non-training control group who showed no improvement. These are very similar to the scale of improvements that an adult would see after a similar training programme. This result confirms what other, earlier studies had also shown – namely, that if intensity, volume, frequency and duration are sufficient, young children can significantly improve their strength by the same relative amount as adults.

'If intensity, volume, frequency and duration are sufficient, young children can significantly improve their strength by the same relative amount as adults'

But no hypertrophy

Further findings from the Ramsay study are also very interesting. While the boys in the study significantly increased their force production, computerised tomography showed no increase in muscle size in the arms and thighs over the 20-week training period. Thus, by inference, the increases in strength must have been due to improvements in the neuromuscular system. Ramsay et al provided evidence for this by showing that motor-unit activation improved 9-12% after 10 weeks and a further 2-3% by the end of 20 weeks of training. This means that the boys were able to recruit more muscle fibres after training and thus produce more force. It is accepted that in adults strength increases as a result of both hypertrophy and neuromuscular improvements. However, it appears, and other studies support this, that children increase strength in training solely from neuromuscular improvements.

Designing programmes

The research describing how a child develops strength, both through natural growth and through training, helps us to design appropriate strength programmes for young athletes. Pre-puberty, both boys and girls have similar strength, and at this age children have developing neuromuscular systems. Strength training for pre-pubertal athletes should focus on skills and techniques; since all the improvements from strength training come from neuromuscular development, this is the ideal time to teach coordination and stability. Children should be taught all the big muscle-group, free-weight and bodyweight movements with light loads. For example, power clean, bench press, press-ups and squats. Any child taught these has an advantage because good technique is learned at a young age, which allows for high-intensity training to be performed safely and effectively as the child gets older. During the pre-puberty years, particular attention should be paid to posture and stability, since children need good strength in the trunk muscles to support the body correctly.

‘If you want children to get stronger, they have to push enough weight, just as adults would’

After puberty

At puberty boys benefit from a massive acceleration in strength because of the large increase in testosterone, which leads to muscle hypertrophy. Girls do not enjoy the same gains in strength, with little muscle-mass development post-puberty, especially in the upper body. At 18, girls have 50% of the upper-limb muscle of boys and 70% of the lower-limb muscle. Almost all the differences in strength between the sexes is due to differences in muscle mass, and if strength is calculated relative to limb volume, ie the force per size of muscle, then both sexes have equal strength.

Girls need to compensate for this natural disadvantage by prioritising strength training from puberty onwards, otherwise strength will plateau. Particular attention to strength must be made by girls involved in sports with upper-body components. Strength programmes for girls from puberty onwards must be effective, with sufficient frequency, volume and intensity.

This is why it makes sense to establish good technique pre-puberty, since from puberty onwards when young athletes need to push weights of 8-12 RM intensity they will already have good technique and enough strength in the stabilising muscles to perform the exercises safely and effectively.

Remember, intensity below 12 RM will target muscular strength endurance and not maximum strength development. So if you want children to get stronger, they have to push enough weight, just as adults would. I recommend that most female athletes visit the weights room two to three times a week from puberty onwards, because it is their lesser maximal strength that is the major factor limiting speed and power in females.

Is it bad for children?

Boys enjoy more natural development during puberty and for a longer time afterwards. In fact, their peak gains in strength last for 18 months after their peak gains in size. However, strength training from puberty onwards would still be highly beneficial for boys. Puberty provides a great window of opportunity for them to develop strength through training because of the high testosterone levels. If regular training is maintained, the large possible gains at this time can last into adulthood. (Without regular training, ie at least once a week, children show the same detraining effects as adults.) For this reason I would also recommend starting 'adult-like' strength training for boys from puberty, depending on the pre-puberty training status. I reiterate that the aim should be to use 8-12 RM loads safely and effectively with pubertal boys by establishing good technique before the time when high-intensity training needs to begin.

Many coaches and parents believe that strength training is bad for children and even potentially dangerous. For instance, a myth exists that heavy weight-lifting too young will stunt growth. There is little research to suggest that weight training for young children is unsafe – in fact, most of it confirms that weight training is one of the safest exercises they can do. A child is much more likely to be injured on the football pitch, tennis court or running track than in the gym.

Weltman et al (1986) specifically studied the effects of heavy strength training on young boys. During the training period, one of the 16 boys suffered a mild muscle strain and none of the boys showed any damage to the growth plates. In fact, strength training in young children will thicken the bones by promoting increased bone mineral density, and do nothing to hinder growth in length.

I repeat once more, weight training with heavy loads is very safe if technique is correct and posture and stability are maintained. Poorly performed weight exercises are just as dangerous for adults as for children.

One final point

When deciding when to start and progress weight training, it is best to use biological and not chronological age as your guideline; otherwise, certain individuals may be starting too late or too early for optimum development.

The following is an example of a strength workout currently being performed by a pubertal male tennis player. This player has been carrying out regular gym training for two years.

Exercise	Weights and reps
Leg press	1 x 20 warm-up, 2 x 10 RM
Bench press	1 x 10 warm-up, 2 x 10 RM
Squat jumps	3 x 10, 15 kg
Lat pull downs	1 x 10 warm-up, 2 x 10 RM
Lunges – jumping	Bodyweight, plyometric
Single arm row	2 x 10 RM
Sit up and throw	3 x 15, 5 kg medicine ball
Twisted curls	3 x 20 bodyweight

Raphael Brandon

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At what age should we introduce our future Rooneys and Wilkinsons to this type of training? A conditioning specialist takes up the story

Mention the words 'resistance training' and 'children' in the same sentence and most people will start giving you funny looks. To say the subject is controversial is an understatement[5, 16]. This is hardly surprising when you consider that until recently the benefits of resistance training to athletic performance have largely been dismissed in the UK. Only now are coaches, athletes and the general public beginning to realise that 'pumping iron' can not only transform your physical appearance but can also improve your health and sporting performance[1,7, 9,14].

As the UK wakes up to the fact that adult athletes can seriously enhance their performance if they adopt a structured resistance training programme, a new question arises: is it too little too late? At what age can we start to introduce our young Beckhams and Henmans to resistance training? For the purposes of this article I am talking about children from the age of 11 and up and it is precisely this age group which many of the world's most successful sporting nations are introducing to resistance training during school training programmes.

So what do we mean by the term 'resistance training'? For some, the phrase will conjure up images of muscle-bound ironmen pumping iron (and much else besides), posing in front of the mirror. In fact, resistance training is simply a programme of exercise, which uses one or more types of training system[1].

Methods include exercises using bodyweight, such as sit-ups, press-ups and dips. Resistive tubing, free weights and machines may also feature in resistance work. Even many of the traditional Olympic lifts, if taught with correct technique and light implements, can substantially improve a child's balance, proprioception, strength and power. What we should not do, however, is confuse resistance training with maximal-type exercises performed during competitive Olympic and power lifting competitions. The key is not to perform maximal lifts with young performers[13].

Why the bad press for resistance training?

The popular myth that resistance training was not only potentially harmful to young performers but was also of little use for improving strength and power was first fostered in the research community. One of the earliest papers came from Eastern Europe back in the early 1960s. A study investigating the trainability of lower back muscles following a course of isometric resistance training failed to demonstrate any significant improvements in strength. Further studies looking at leg and arm strength also failed to find any substantial strength gains[18]. During the next couple of decades a groundswell of support backed the notion that resistance training methods failed to provide significant increases in strength in young performers. As is often the case, subsequent research built upon the limitations of earlier investigations.

So why did earlier studies fail to provide evidence of strength gains? The 1960s investigators used only modest training loads, resulting in a lack of progressive overloading (possibly one of the most important training principles, irrespective of the training method being used). When combined with relatively short monitoring periods, it is hardly surprising that little or no improvement was seen.

Modern training theory now confirms that, in order to achieve significant strength gains in young athletes, training mode, intensity, volume and duration must all be manipulated to provide the optimal combination. Researchers and coaches alike are now confident that if a suitable resistance training programme is employed, significant strength and power gains in young performers are possible[5, 10,11].

In recent years research has started to provide compelling evidence of the benefits of resistance training. Training programmes incorporating progressive overloading of the muscles have provided evidence that strength gains in young athletes is possible (even if they have not gone through puberty). In 1986 a group of boys aged between nine and 10 embarked on a period of resistance training. At the end of the training period significant increases in elbow and knee flexion and extension were recorded[11].

Further studies found that over a period of 20 weeks, progressive overloading of the elbow flexor and knee extensor muscle groups, using isotonic training techniques, produced significant increases in strength[12]; 1RM double leg press (22%), maximal voluntary isokinetic elbow flexion (26%) and knee extension (21%) were achieved.

‘More recent studies have shown that strength can be improved even in the absence of muscle hypertrophy’

Yet again, it has a lot to do with neurological systems

So recent evidence has shown that resistance training could be a useful tool in the coach's 'toolbox' of training ideas. But you may find yourself asking: how can a boy who has yet to go through puberty (and has therefore yet to have testosterone coursing though his body) possibly experience gains in strength. Surely, gains in strength are related to muscle hypertrophy, which is influenced, by the amount of testosterone in the body? Early research showed that the young athletes were not experiencing significant gains in muscle size (as would be expected with adults) and, when coupled with the lack of strength improvement, it seemed sensible to conclude that resistance training was of little benefit. However, more recent studies have shown that strength can be improved even in the absence of muscle hypertrophy. The question is: how?

What the early studies failed to recognise was that children are not just miniature adults and that the mechanisms which bring about an increase in strength in adults may differ for children. So how can children improve strength if testosterone is not responsible? Testosterone does not start to increase until mid to late puberty, effectively ruling out the male hormone's contribution to strength gains in young performers[16].

And, given that girls (who, of course, don't produce testosterone) can also improve their strength, that very fact points us in the direction of a different explanation.

Theorists have pointed to the possible contribution of neurological systems[10]. Evidence suggests that strength increases in line with the development of the nervous system, which is of primary importance in the exertion and development of muscular strength[16]. Research has indicated that there are three likely determinants of strength gains: improved motor-skill coordination; increased motor-unit activation; and undetermined neurological adaptations[16,13].

Early theories were based largely on indirect supposition and so direct assessment of these neurological adaptations was needed. Using ground-breaking techniques, researchers investigated the changes in motor-unit activation (MUA) following a period of resistance training in pre-adolescent boys[12]. Results indicated that after the first 10 weeks of training, MUA of the elbow flexors increased by 9% and MUA of the knee extensors increased by 12%. Slower increases in MUA were recorded during the second 10 weeks. The results confirmed current thinking that the nervous system has many roles to play in improving athletic performance.

Subsequent research confirmed that strength gains in young performers could be attributed in part to increased neuromuscular activation. Both MUA and motor coordination increase still further when multi-joint complex lifting activities are used rather than isolated movements. Specificity is important for improved motor coordination: researchers have demonstrated that more significant improvements in strength occur in the specific exercises performed during training than with non-specific exercises such as isometric elbow flexion and knee extension[1].

Can you really swim faster, jump higher and hit harder?

While you may be prepared to accept the body of laboratory evidence which shows that resistance training can improve strength in young performers and that the dominant underlying mechanism is neural in origin, it is legitimate to ask whether this can be translated to the sporting arena. It has been said that the stronger an individual is, the higher he will jump, the faster he will run or swim and the harder he will hit a ball. Sports such as netball, rugby, athletics, tennis and cricket all require strength and power in order to perform complex multi-joint movements. It's not unreasonable, based on the research, to suggest that the results seen in controlled laboratory studies could be transferred to the sporting arena. Although there is limited direct research in this area, studies have shown that intensive resistance training can improve both strength and swim speed in pre-adolescent boys and girls[2]. Indirect evidence has shown that an increase in strength can improve specific activities, such as vertical jump, swim speed and running speed[15] and, if you look at the investment most high-performance teams are now making in strength training for their performers, I would suggest that resistance training is an extremely effective tool for improving athletic performance.

If you are still not convinced about the impact resistance training can have on performance, just look at leading sports performers from a decade ago and compare them with those competing now: today's competitors are bigger, stronger and faster than ever before. While the cynical may refer to illegal aids, the more astute will recognise that sports performers are increasingly using resistance training to help improve their performance. Although there is limited research on youngsters, it is reasonable to suggest that younger athletes could also enjoy the same type of improvements in athletic performance seen in adults following a period of resistance training.

But what about injuries? Surely, all that training can't be good for young bodies? In 1987 the US Consumer Product Safety Commission reported that resistance training was a harmful activity for children[1]. The report highlighted the disturbingly large number of injuries associated with resistance type exercises; 8,543 injuries were incurred by 0- to 14-year-olds and ranged in severity from sprains and strains to fractures. Approximately 40% of the injuries occurred during unsupervised sessions in the home. A subsequent study investigating sport-related injuries in school children taking part in 22 sports found that resistance training produced just seven injuries from a total 637, placing it 17th on the injurious list[17]. The message is clear and obvious: if young athletes play around with weights at home or during unsupervised sessions they could well end up in their local A&E department. However, if you closely supervise your young athletes during resistance training sessions, ensuring they follow a structured training programme, they should be at no greater risk of injury than when they are taking part in their chosen sport.

'If you closely supervise your young athletes during resistance training sessions, ensuring they follow a structured training programme, they should be at no greater risk of injury than when they are taking part in their chosen sport'

But what about the immature musculoskeletal system?

Another area of concern is the potential damage resistance training can cause to the immature skeleton: increased physical activity in children is often associated with musculoskeletal damage[4]. The skeletal system is in its formative stages during pre-adolescence and does not fully mature until early adulthood[6,8]. It is commonly thought that the use of resistance training could contribute to damage of cartilage, bones, joint surfaces and tendons. It has even been suggested that damage to growth cartilage can result in stunted growth. Other structures, such as the spine, have also been highlighted as an area of potential injury. Although these issues are a serious cause for concern, some experts feel that the case may be somewhat overstated. Research has shown that sport-related musculoskeletal damage occurs very rarely. The majority of cases have been linked with maximal overhead lifts of the sort associated with power lifting, and no evidence has been found of skeletal damage in relation to resistance training[1].

So, based on sound research, it would be safe to say that a good-quality resistance training programme is an effective training method to complement the existing training regime of young performers. If you are a coach looking to introduce your young athletes to the benefits of resistance training, here are some guidelines to take into consideration.

The young performer:

- should complete a medical examination by doctor before starting the training programme;
- should be mature enough to accept instruction;
- should want to participate in the programme;
- must possess the basic motor skills of their primary sport;
- must maintain correct form during lifting;
- must avoid competition during training.

For his or her part, the coach should:

- ensure the young performer is closely supervised during training sessions;
- ensure the training offers variety;
- pay particular attention to the strengthening of the back and abdominal muscles;
- ensure that in the event of any pain, training is discontinued;
- ensure that the resistance training programme forms part of a comprehensive programme designed to increase motor skills and fitness levels;
- ensure that all exercises are carried out though a full range of motion;
- prohibit any attempts at maximal lifts.

If resistance training is a new area to you, here are some of the basic guidelines you should think of when putting together a training programme:

1. Begin and end each session with 5-10 minutes of warm-up and stretching.

2. Balance the workout by altering pairs of muscle groups, ie perform a 'pull' exercise after each 'push' exercise. (Examples of pull exercises are barbell or dumbbell bent over row, cable lat pulldown, seated row; push exercises may include barbell, dumbbell or machine bench press, squats and shoulder press.)

3. Exercise the larger muscle groups (pectoralis major – chest;

latissimus dorsi – back; quadriceps) first, and the smaller muscle groups (biceps and triceps – arms; deltoids – shoulder; gastrocnemius/soleus - calves) at the end.

4. Perform 1-3 sets of 6-15 repetitions. Younger children may use fewer sets and more repetitions.

5. Allow 48 hours of recovery after each strength training session.

6. Work on the schedule 2-3 times per week while maintaining other sporting activities.

7. Younger children can spend 20-30 minutes per session while older children can increase the duration of each session.

Nick Grantham

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Encouragement and support without pressure is the key with kids

Bruce Tulloh, former European 5,000m champion, noted coach and author and father to three national-level runners, offers some thoughtful advice to the parents and coaches of aspiring athletes

The key to successful coaching of children – whether by parents or professionals – is to tackle each phase of development differently, according to its context. We would all like our children to be Olympic champions, but the worst thing you can do is pressurise your children with your own dream of glory and then blame them for not realising it.

'The worst thing you can do is pressurise your children with your own dream of glory and then blame them for not realising it'

At each stage in life the developing boy and girl have their own reasons for getting involved in sport. It may be a desire for approval, or a wish to make a mark in his or her peer group. More likely, it comes from discovering an aptitude for the sport, which brings a modicum of success. We all need to find things we can do well. Self-esteem feeds on achievement, and sport at club level is an excellent way of doling out spoonfuls of achievement on a regular basis.

Ages 7-11: avoiding 'little league syndrome'

We hear of football clubs sending scouts to primary school matches, and the 'pushy parent' phenomenon – or what the Americans call 'little league syndrome' – can appear at a very early stage. But at this age sport is just play, and it does not matter who wins. Children need exercise: they need to develop their bodies and their brains, and the best way of doing this is by having fun at the same time.

Exercise also offers a way of learning about the world and how it works. Sport, like life, has its rules, its constraints, its set boundaries. Like life, it tries to be fair but doesn't always succeed. The child learns the hardest but most valuable lesson of all – that he has his limits. The parent has to find out what the child can and can't do well. He must offer the child lots of opportunities and help him to select the ones which will best help him grow as a person.

The 'Tiger Woods model' is not a good one to follow, because this involves a parent imposing a regime at an age when the child is not in a position to make a choice. For every success this model produces, there are hundreds of frustrated children who are being blamed for not living up to their parents' expectations.

During the primary school years, the child should be encouraged to run, but not forced to do so. A common reason for running is to be like Mum and Dad, and this is fine. If there is a local club which caters for under-9s and under-11s, encourage them to go along, as long as the regime there encourages variety and non-specialisation.

How far should a child run at this age? Basically, they can run for as long as they want, as long as it is at their own pace. The biggest danger for modern children – particularly city kids – is lack of exercise, producing a downward spiral where inactivity leads to obesity, which makes them less inclined to do anything. Long runs on tarmac are not a good idea, but there is no reason why they should not go out training for 50 or 60 minutes, as long as this time is broken up. Children have the common sense to slow down or walk when they feel tired.

A typical pattern for a club evening might be:

- 5 minutes running round the field
- 10 minutes of exercises, usually with a partner
- 4-8 laps of the track (1-2 miles) broken up into fast and slow sections
- 15 minutes practising a skill (eg a jumping or throwing event)
- 2 short-sprint relay races, in different teams
- 5 minutes continuous relay (paarlauf)
- 2 laps slow jog.

The emphasis in this phase should always be on variety. If a child is doing some kind of sport four times a week, that is fine, but the four days might include football, swimming, judo or cycling as well as running.

Ages 11 to 13: resist the urge to specialise

At the beginning of secondary school, the child's choices are generally guided by parents and teachers. The urge to specialise in one particular thing must be resisted: all the evidence is that those who keep up a variety of sports up to age 14 are more robust and less fragile than those who specialise early. Early specialisation may bring short-term success, but is that really what you want?

At this age there will be a huge difference between early and late developers. The arbitrary nature of the age-group system may lead to immature just-11-year-olds running against overdeveloped 14-year-olds. Coaches and parents must be careful about throwing children into competition before they are ready for it, but they should not avoid competition entirely. People develop by overcoming challenges, and the art of coaching lies in finding the right sort of challenge for each kid.

My own three children all became successful runners. My son Clive was a slow developer, like me, but always wanted to be a runner. When he was 11, he wanted to run in the county under-15 championships. I said I didn't think it was a good idea, but he said: 'So what if I come last, it won't kill me'. He came 72nd out of 75 and it didn't kill him. He has a strong drive to succeed and trained hard through his secondary school years, getting up to national class on the track when he was in the sixth form and eventually winning a British Universities title.

My twin daughters Katherine and JoJo had a huge amount of natural ability and by an accident of birth were at the top of their age group. As first-years, they completely demolished the local opposition. In some ways it is harder to coach the very talented: you can't dangle the carrot of success under their noses, because they have already eaten it.

With the majority of kids of this age, the right approach is to encourage team spirit, in a club or a school team. This enables the slower developers to get satisfaction from the team success. The more successful fast developers must be shown that they need the others if they are going to win their match or get a medal in the relay. With some short-term goals ahead of them, training should be done once or twice a week, but integrated with all the other physical activities such as games and PE lessons.

Ages 13 to 15: Taking social life into account

During this phase the child has a far bigger share in the decision-making process. The other feature of this age group is that social activities have to be taken into account. The sport has to be handled in such a way that it does not conflict directly with the other developing interests. Again, if there is a local club with a good team spirit, it will provide the support and companionship which is so important at this age.

By this time it will be clearer where the child's talents lie. However, the really talented track runner may be needed for the football or the hockey team in the winter, when most runners are doing cross-country. This should not be a cause for worry, because some running training can be added to the football, and there is plenty of time to get fit for the track season if you start training in March.

Training can now become more organised, but other sports can still be kept in. A typical pattern might be two nights a week of club training, plus a Saturday race, to which can be added one or two more steady runs on the days when there are no other sporting commitments. It is important at this age that someone keeps a training diary, so that the youngster's state of fitness is clear and training can be increased gradually year by year.

Training will not yet be all-year-round. The growing body has to be released from the stresses of continuous training, even though the training may be beneficial. Natural breaks will occur in the school holidays, with family visits, skiing trips and travels abroad, and neither the athlete nor the parent should worry unduly about this. A vital point to appreciate is that training too little will not prevent the athlete from eventually reaching full potential, but pushing the athlete too hard in training or competition might well do so.

A highly-motivated athlete with several years of running experience may be able to handle a lot of training, but this won't suit everybody. The highest-ranked athlete I have coached, Richard Nerurkar, who went on to be Britain's best runner at 10,000 metres and the marathon, was running 50 miles a week when he was 14 – but he also stopped running in the summer when he was working for his exams. Tegla Loroupe, the world record-holder for the marathon, was jogging 10 kilometres to school every morning when she was 11 and another 10 in the evening – but this was normal in rural Kenya.

My own daughters were running 20 miles a week at age 14, which meant roughly four miles a day, five days a week, with two of those days including some kind of speed work. This was enough to enable them to run under 4 mins 40 secs for the 1,500 metres at 14 and get down to 4 mins 25 secs the following year. This is also the level of training I used for my school teams in this age group. The pattern was normally to build up endurance in the autumn, with some road relays and school matches as the target, and then to focus on cross-country, building up to the English Schools races in March before turning to track training in the summer.

Age 16 and over: relating training to ability

From this point on the parent is a consultant, not a dictator. The level of training is related to the ability of the athlete. At sixth-form level, a distance runner might be running 30-40 miles a week – enough to bring out the talent and carry on with A levels. One of my Marlborough College athletes achieved three grade-A A-levels in summer 2000 and made the GB Junior team the following spring, having stepped up his training since leaving school.

A really talented athlete may be on the fringe of international level at 17. In this case, some adjustment may be made to allow more time for training. On the whole, it is better to stay on in education as long as possible, because sport and education can be combined more easily than sport and work. With a year off and three or four years of college, the athlete has a real chance to develop his full potential.

On the other hand, parents must accept that puberty brings huge psychological as well as physical changes, and priorities will change. My own daughters, who at 15 were beating Kelly Holmes, had lost interest a year later. Art, Life and Literature became much more important to them, and as parents we had to accept their choice. Although we lost them as athletes, we kept them as daughters and friends. They went on to become happy and successful in other ways, and I am sure that the discipline and the confidence they gained from their running has helped them in later life.

So I say to parents: 'Enjoy each phase in your child's athletic career, but keep things in proportion: it is their sport and their life.'

Bruce Tulloh

WHAT THE SCIENTISTS SAY

Can creatine work for younger performers?

Creatine is extremely popular with adult athletes, many of whom believe it gives them a performance-enhancing boost. But does creatine offer any ergogenic benefits to young performers? A group of sport scientists based at the University of San Francisco have examined all the available research in a bid to establish a rationale for creatine supplementation in child and adolescent athletes.

The main argument for the use of creatine in this age group is that children struggle to use and reproduce creatine phosphate and ATP effectively, so limiting their ability to regenerate high-energy phosphates during exercise. Creatine supplementation, it is suggested, could help children improve their performances in high-intensity exercise. However, there is a lack of compelling evidence to support this theory and a number of arguments against it. Here are the main ones:

- children are not mini-adults and have a greater reliance on aerobic rather than anaerobic metabolism. If the goal of creatine supplementation is to enhance anaerobic metabolism, it would therefore have a limited effect;
- adolescents appear able to regenerate high-energy phosphates during high-intensity exercise and improve performance in short-term high-intensity exercise through training, therefore reducing the need for supplementation;
- performance during growth tends to be limited by mechanical factors rather than by the relative contribution of the aerobic and anaerobic energy systems;
- the long-term safety and efficacy of creatine supplementation has not been established in children and adolescents.

However, the arguments for and against creatine supplementation in children and adolescents are derived from an extremely limited number of studies. A significant amount of research is needed to enable us to fully understand the metabolic changes that accompany growth before we can even start to consider the efficacy and safety of creatine supplementation. With this in mind the research team concluded that there was insufficient evidence to support the use of creatine by children and adolescents.

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Young female athletes should not stop menstruating

Absence or cessation of menstrual periods is not a normal response to exercise in adolescent athletes and should lead to a complete medical evaluation: that is a key recommendation of the American Academy of Pediatrics' Committee on Sports Medicine and Fitness, which has issued guidelines to paediatricians on monitoring the health of young female athletes. The recommendations are equally relevant to British coaches, parents, health professionals – and anyone concerned with ensuring that youngsters' health and normal maturation is not compromised by performance requirements.

In a paper published in *Pediatrics*, the committee identifies three key concerns:

- Disordered eating, which may be unintentional (when energy supply does not keep pace with expenditure) or deliberate (a conscious attempt to lose weight or body fat to improve appearance or athletic performance). Sports that may place athletes at higher risk for the development of eating disorders include those in which leanness is emphasised (eg gymnastics, ballet dancing, diving and figure skating) or perceived to optimise performance (eg long-distance running) and those which use weight classification (eg martial arts and rowing). In fact, disordered eating – including bingeing and purging, as well as food restriction – may impair athletic performance and increase the risk of injury as well as causing dangerous medical and psychological complications;

- Menstrual dysfunction, which can be caused by disordered eating, and is more common in athletes than the general population. This in turn may lead to...
- Decreased bone mineral density (BMD), leading to premature osteoporosis. According to the committee, girls who start menstruating at a later age, and have a lower weight during adolescence than their peers, have been found to have the lowest BMD.

'The physical examination that precedes participation in sports is an ideal opportunity to screen for problems of disordered eating, menstrual dysfunction and decreased BMD,' say the authors. 'Signs of disordered eating may be recognised by parents, coaches, athletic trainers, teammates or school nurses and brought to the physician's attention.' After that, further evaluation, with input from a nutritionist and a mental health professional, may be necessary.

Increased dietary intake or decreased energy expenditure usually result in the development or resumption of menstruation, resulting in turn in increased BMD, although some bone loss may be irreversible.

Other recommendations are as follows:

- Dietary practices, exercise intensity, duration and frequency and menstrual history need to be reviewed during medical evaluations of young athletes;
- Disordered eating should be suspected in adolescents with amenorrhoea (menstrual dysfunction) and may require treatment by a multi-disciplinary team of health professionals;
- Athletes, parents and coaches should be counselled on the perils of disordered eating, menstrual dysfunction and bone loss and educated on the constituents of a healthy diet;
- When athletes and coaches seek details of the recommended weight and percentage body fat, it is best to offer a range of values. 'It is difficult and potentially dangerous to define an ideal level of weight and/or body fat for each sport or individual

participant. Weight is not an accurate estimate of fitness or fatness, and when weight is lost, muscle and fat are lost';

- An adolescent with menstrual dysfunction attributable to exercise should be encouraged to increase her energy intake and modify excessive activity. If her weight is low she may need to gain weight before resuming athletic activity.

Reference

(Pediatrics vol 106, no 3, September 2000, pp 610-613)

How training boosts endurance capacity in young children

As readers of this special report will already know, what determines the endurance capacity of the growing child has always been a difficult issue to untangle because growth itself gives a powerful boost to aerobic fitness. But recently a Hungarian study has shown quite clearly that habitual physical activity has a marked effect on endurance performance in children under 10.

The aim of the investigation was to define the actual level of aerobic endurance performance in children aged seven to nine and to analyse the relevant factors that may affect this kind of performance in the light of different levels of sport participation.

Two primary school classes containing a total of 42 children were selected for the experiment. All the children had physical education classes five times a week, but the children in one group took part in additional regular sport courses – such as basketball, karate, swimming and gymnastics – at the school's own sports club, while the other group served as less active 'controls'.

Aerobic performance was estimated at the beginning of the experiment, when the children were aged seven to eight, and again one year later, when they were eight to nine, by measuring cardio-respiratory response during a treadmill run using an all-out testing protocol. At the same time a number of anthropometric measurements were taken, including body composition and musculo-skeletal development.

When first tested , the children in the athletic group had lower fat values, greater muscle mass and higher maximal heart rates than the controls. After a year their endurance performance had improved much more than that of the controls: the increase in VO_2max in the latter group slightly exceeded 200ml/min – about what has been reported as normal in the pre-pubertal years – while the athletic group boosted their VO_2max by almost 400ml/min.

'The athletic group performed more mechanical work and displayed a better economy in running than the non-athletic group,' say the authors. 'This improved running performance was associated with a comparable respiratory exchange ratio. [Other researchers have] found that running efficiency in children improved with growth, ie, when performance was similar, the contribution of aerobic metabolism to work became larger. Our data showed that this tendency was stronger in the more active children.'

Reference

(Acta Physiol Hung 1999;86(3-4):229-35)

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