SOME FEATURES OF THE ANATOMY AND EXERCISE PHYSIOLOGY OF CHILDREN, RELATING TO TRAINING

By Craig Sharp

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Although children between 11 and 16 are the fittest section of the community their activity patterns are continuously frilling. One important cause of this is that, at least in Great Britain, school sport is declining. With this background of falling activity the health of the future adults will depend increasingly on coaches to instill an enthusiasm for lifelong adherence to health-related activity patterns.

As children show considerable and important differences in their bodily responses to exercise, compared to adults, it is important that coaches are aware of the more important differences to avoid imposing undue physical stress on their young charges.

Against this background the author discusses some anatomical and physiological aspects which must be considered when coaching children and adolescents. He arrives at the conclusion that the safest course for the coach is to plan shorter periods of activity than would be the case in an equivalent adult squad.

In coaching situations there should be frequent short rests, with exercise periods of about 15 to 20 minutes. Especially pubescent girls who may be new to menstruation should receive sympathetic treatment in the sports / exercise situation.

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Children from 11-16 are relatively fit; indeed they are the fittest section of the community. The worry is not children’s fitness, with its high genetic component, but their low activity patterns - because much evidence suggests that it is these patterns of childhood activity which, to a considerable extent, determine their future activity patterns as adults. Inactivity now ranks as one of the major items most amenable to positive change among those implicated in the causation of coronary heart disease (CHD), along with smoking, diet, high blood pressure and being overweight (sedentary lifestyle increases the CHD risk by a factor equivalent to smoking 20 cigarettes per day). Thus, quite apart from the pleasure of sporting success and the sheer enjoyment of sport - it would seem especially important to tackle the inactivity habit at source, namely in childhood.

As children show considerable and important differences in their bodily responses to exercise, compared to adults, it is important that coaches are aware of the more important differences to avoid imposing undue and unwitting physical stress on their young charges, possibly giving them negative feelings about sport - and hence exercise. I will discuss the anatomical side first, followed by physiological aspects.

Anatomy

Growth spurt

Children do not grow at an even rate, but in a series of fits and starts, by far the greatest of which is the ‘adolescent growth spurt’ which occurs around puberty, in which children may grow up to 15cm over its two-year duration. This in itself may well upset techniques in the high body-skill athletics disciplines such as high jump, pole vault, and long and triple jump. The growth increase commonly starts at any age between 10 and 12 in girls, and between 12 and 14 in boys, although in both it may start even later, or occasionally earlier.

This brings two sports problems. Those who enter the growth spurt early often do very well in age-group athletics, so become used to success without training very hard. In their later teens however, when their slower-growing peers catch up, they are unused to being beaten, and often drop out of the sport. Equally, many of the later candidates for the growth spurt may feel hopelessly overpowered from the start, and believe simply that they are ‘no good at sport’. Thus both ends of this normal distribution should be spotted, and counseled accordingly.

Skeleton

Before the growth spurt, both sexes are much the same in terms of their skeleton, but afterward the girls end up with broader hips and the boys with broader shoulders, on average. The boys also tend to have relatively longer and straighter arms. Their broader hips, with resulting more steeply angled femurs, may cause some girls to throw out their heels when running, so attention needs to be paid to running technique. Also, more sharply angled thighs with most of the muscle on the lateral aspect leads to greater lateral forces at the knee, as the quads exert a ‘bowstring’ force at the patella, tending to push it outward. This can be a factor in the condition of chondromalacia patellae, one cause of 'runner's knee'.

One preventive measure, which can be started soon after puberty in the broader hipped girl, is for her to strengthen the vastus medialis muscle, which is the only one of the quadriceps group to exert force medially on the patella, i.e. it works to counteract the bowstring effect just described. A good medialis exercise consists of five to ten reps of slowly straightening the leg under a moderate load (about 60 per cent of maximum), on the quads station of a multigym for example, and holding it straight for about five seconds before relaxing. Even daily straight-leg 10 second isometric contractions, under a desk, or in a bus or car for example, are beneficial.

Nine-year-old boys and girls have virtually the same bi-acromial breadth across the shoulders, but by the age of 19, males are about 4 cm broader. The longer arms and greater shoulder breadth and associated muscle mass of the boys explains the greater relative difference in upper body strength compared to the lower body, between the sexes. It is illustrated by the difficulty many older girls have in doing press-ups, although they may have very respectable vertical jump scores. For the same reason, females more closely approach male performance in running events, compared to the throws.

This widening of girls' hips causes a fall in their centre of mass, hence they tend to become more stable. In contrast, the boys' rising centre of mass renders them less stable, which may be reflected in the balance beam being a gymnastic discipline for females but not for males. This same factor disadvantages older girls in the high jump.

Some girls develop a pubertal valgus or 'carrying angle' in their arms, shown when they hold their arms by their sides, palm facing forward, when the forearm is seen to bend laterally to a varying degree. Many girls who have been active in sports involving the arms since well before puberty, e.g. artistic gymnastics or swimming, have two relatively straight arms, or in tennis, one straight arm (the racket arm). A girl with a marked valgus angle who wishes to take up javelin-throwing for example, might encounter elbow problems, and may be better going for the shot or discus.

Bone damage

The long bones of the limbs grow from the epiphyseal plates, which may be damaged by severe and excessively repetitive overload-stress before full growth is attained. However, correct programming allied to good techniques in weight-training does not seem to bring about bone problems in young athletes. Anabolic steroids given before the completion of growth (as exemplified by recent reports on 14-year- old girls in South Africa) may stunt growth by calcifying the epiphyseal plates and stopping further lengthening of the limb bones.

In the arm, relatively little growth occurs at the distal end of the humerus, or at the proximal end of the radius and ulna, but in the leg, most of the growth of the femur, tibia and fibula occurs at the knee, so children's fractures around the knee must be rehabilitated with particular care.

Complete fusion of tendons to their respective apophyseal locations on bone occurs at different ages between 12 and 20 for different sites, potentially leading to a number of 'traction' injuries, e.g. Osgood-Schlatter's disease at the tibial tuberosity (12 to 16) in young runners and jumpers, or Sever's disease at the calcaneum of the heel (10 to 13) again in young runners and jumpers. The iliac crest, at the top of the hip bone, is especially vulnerable to 'apophysitis' between 14 and 17, especially in events involving twisting the trunk, such as in the throwing events and in hurdling. Similar apophysites may occur in the shoulder and arm in young throwers. Such traction stresses, associated with 'crescendo pain', occur particularly through high repetition training.

Body fat

During early childhood, boys and girls have much the same amount of body fat, at approximately 16-18 per cent. Through puberty, girls are programmed by their increasing hormones to lay down more fat, specifically in the breasts, hips, thighs and triceps, while boys correspondingly reduce their fat. Thus by 18, the girls' body composition may include 24-28 per cent fat, but with only 12-16 per cent in boys. In girls these fat changes lead to a relative lowering both of aerobic power and of muscle strength and power, so coaches should be on the look-out for this. Some adolescent girls are particularly sensitive to body-shape changes in terms of their perceived body image, and if coaches and others over-encourage leanness, they may lapse into anorexia nervosa. A significant proportion of older girls, already with a tendency to anorexia, come into sport because it seems to legitimize leanness! Again, the coach should be on the look-out for this, from around 14 years onward. This subject is worth taking very seriously, as the eating disorders carry a mortality rate of up to 15 per cent. The problem does also occur in males, although more rarely.

It is worth noting that many obese children are not necessarily greedy. Part of their fat build-up is due to fairly normal levels of eating, but with very low levels of exercise. Even when playing sport, whether swimming, hockey, football, rugby etc. - they often do far less physical work than their non-obese peers. So again it is worthwhile for the coach to look out for this, and to try gently to increase the workrate of the plumper children in recreational athletics, who may often be directed toward the more static throws, rather than the more calorific runs (in football and hockey they are often put in goal; and in swimming they stay warmer; so have less incentive to keep active!).

Physiology

Menarche

Menstruation normally starts during the other reproductive changes of puberty, namely mammary development, pubic hair, and shape changes. There is some evidence that menarche and indeed puberty itself may be delayed in youngsters who have been intensely involved in very physical sports from a very young age. As a rule of thumb, it has been suggested that every year of hard training undertaken before menarche, delays it by five months.

The thin runner of 15 may partly be a result of the sport itself. In addition, very intense exercise, especially sustained aerobic exercise such as distance running, may, through the hypothalamic-pituitary-ovarian axis, stop menstruation from occurring at all - or stop it once it has occurred. About 70 per cent of women runners training over 70 miles per week will expect to have partial or complete amenorrhoea. Amenorrhoea implies low oestrogen levels, which in turn may lead to calcium loss, giving a degree of osteoporosis. This may lead to susceptibility to stress fractures - and it may very well lead to skeletal problems in later life by lowering the post- menopausal fracture threshold. So coaches should keep a watchful eye on keen young female runners who have gone through puberty, but who show oligomenorrhoea (irregular periods) or amenorrhoea. Lowering the training volume (ideally so that the athlete has about four periods per year), increasing the food intake and increasing the (skimmed) milk intake, (and even introducing the contraceptive 'pill' - with its oestrogen component), may all help. Medical advice should of course be sought.

Aerobic

The aerobic side of exercise involves heart, lungs, blood and the muscle fuels used. Heart rates in children may reach 220 or even 225 before puberty, but tend to fall to around 200 in their late teens, so the coach should not worry on finding such high rates in exercising youngsters.

Also, children tend to breathe faster than adults, reaching 60 breaths/minute compared to 40/minute in adults doing equivalent exercise. Compared to adults, children need to breathe more air to get the same amount of oxygen, i.e. their 'ventilatory equivalent for oxygen' (the number of liters of air to gain one liter of oxygen) is higher. This is wasteful of energy and body water (in the breath). Occasionally it may lead to 'hypocapnic tetany', whereby very high respiratory rates may lead to an excess blow-off of carbon dioxide, which increases the blood pH or alkalinity, affecting blood calcium and nerve function, and leading to a degree of spasm in feet and hands, and numbness around the mouth.

Such hypocapnia may occur in the heat, as in training and competition in summer, but increasing numbers of cases are being reported outdoors in winter

— for example from junior rugby matches. The condition is not at all serious but the young victim may panic, and alarm onlookers. A simple cure is to get the child to re-breathe his or her own air for a few minutes, (e.g. from a paper bag) so raising the carbon dioxide and normalizing the pH levels.

Children's muscle tends to use more fat as fuel than glycogen or glucose. However, for the same amount of energy, approximately 10 per cent more oxygen is needed, if fat is the substrate compared to glucose/glycogen, so it is a less efficient fuel. Children also tend to utilize glycogen or glucose more slowly the younger they are.

Thus the younger the child, the less efficient aerobically, they are made worse by relative biomechanical inefficiencies, in that the lengths of younger children's limbs are not completely in 'kinetic balance' with their muscles. They also have proportionately less body mass in muscle - some 28 per cent in young children, compared to 35-40 per cent or more in the late teens.

So in walking or running, the younger the child, the harder they have to work, relatively, to keep up with even a slow adult on a moorland or hill walk, or on a training run. Interestingly, riding a bicycle evens-out much of the difference between younger and older children, and children and adults, partly through its gearing, and partly because body weight is supported, thus compensating for the lower proportion of muscle (the smaller engine) in the young child's body.

Nevertheless, young children incur less of an oxygen deficit at the beginning of exercise - i.e. they get their 'second wind' quicker. As their deficit is less, so they also recover quicker. They also have higher 'anaerobic thresholds' than adults, and in this, oddly enough, they resemble trained adult endurance runners.

Anaerobic

On the anaerobic side, the younger the children, from about 8 to 16, the lower the proportion of anaerobic energy they can generate, and the lower the levels of lactic acid in blood. Thus, the younger the child, the less they have a built-in fatigue mechanism. An important physiological function of fatigue is to prevent muscle damage through excessive effort. Young children, without the same early-warning fatigue system as their elders, can easily be pushed in team or individual coaching sessions to the point where they are overheated, dehydrated and distressed.

Heat regulation

Children produce more heat per kilogramme body weight than adults, but their thermoregulatory system is not as good. This is partly because they sweat less. For example, a 12-year-old boy may sweat 400ml per square meter of skin per hour, compared to an adult man's 800ml. Girls and women sweat proportionately the same, although less in absolute quantity terms. Children also tend to have higher skin temperatures, which hinder the flow of heat from body core to the periphery. However, children have a proportionately greater skin surface area the smaller they are. A young adult weighing 64kg will have a surface area of about 1.80 square meters; An eight year- old weighing 25kg will have a skin area of 0.95 square meters, i.e. 36 per cent more surface area per unit of weight. This helps to correct thermal imbalances, but can be a disadvantage when running in direct sun (or swimming in cold water) - with the possibility of a faster rate of overheating (or of overcooling).

Perception of exertion

Thus it can be seen that the younger the child, the less are the built-in protective mechanisms evident in the late teenager or the adult. This is all made worse by the fact that young children's perception of the severity of exercise is less the younger they are. Adults, or late teenagers, working maximally on a treadmill (or a rowing, canoe or cycle ergometer) will indicate 'maximum' on the Borg scale of perceived exertion. But young children, also working at or near their maximum will often indicate just above mid-way on the scale. Their perception of severity is less. Adults sensibly stop when exercise is too hard; children tend to press on. In sports and training situations, this can lead to their overdoing it, and becoming genuinely exhausted, over-heated and possibly dehydrated.

In summary

The safest course is for the parent, coach or teacher to plan shorter periods of activity, where feasible, than would be the case in an equivalent adult squad. In coaching situations, there should be frequent short rests, with exercise periods of about 15-20 mins, and the children should drink, even 75-100ml of water or squash, in the breaks. Any who look over-heated should be checked. As an overall policy, the large, the small, the fat and the very thin should all warrant extra observation - they all may have their own problems.

Pubescent girls who may be new to menstruation should receive sympathetic treatment in the sports/exercise situation, as should children of both sexes who may have problems with 'constipation-with-overflow', and those with 'crescendo limb pain'. Not all reluctant sports-children are wimps! Even those who are, need quiet encouragement and sensitive handling to help them gain or regain their confidence.