An increasing number of children take part in organized sporting activities, undergoing intensive training and high level competition from an early age. Although intensive training in children may foster health benefits, many are injured as a result of training, often quite seriously. This paper reviews some of the areas of research dealing with intensively trained young athletes, and focuses on physical, cardiovascular and muscular effects, sports injuries and psychological effects of intensive training. It is concluded that measures should be taken to modify present training and competition schemes to avoid the deleterious effects of intensive physical activity on these children.

Keywords: Intensive training, children, sports injuries

In the past few years, competitive sport participation has become an established feature of Western society. Youngsters in their early teens may have already undergone intensive training and high level competition for several years in sports like gymnastics, swimming or tennis. Rowley has reported that early participation of children in competitive training activities is due to the 'catch them young' philosophy, and to the belief that, to be able to achieve international acclaim, it is necessary to start intensive training before puberty.

The number of children taking part in competitive sports is so high that some medical bodies have issued guidelines regarding participation. Although all the risks of injury in these youngsters are, at present, unknown, an epidemic of sports injuries, as children change from free play to the stereotyped demands of the specialized patterns of movement imposed by a single sport, has been predicted.

The emphasis on intensive training and high level competition in a single sport begs the following questions:

Should young children participate in intensive training and high level competition?
Are children involved in intensive training at risk of injuries to their developing musculo-skeletal system?
Can psychological problems arise from intensive sports participation at a young age?

Physical, cardiovascular and muscular effects
Increase in strength and endurance are an established feature of growth and development and of training. The effects of physical training are difficult to separate from those of normal puberty. Studies involving children have detected a wide range of results, from certain ill effects, such as growth retardation, and no effects at all, but the minimum needed has not been identified, and the ill effects of intensive training have not been fully clarified.

In girls, one of the most sensitive areas of research has been menarche and menstrual disorders. The age of achieving menarche, and the incidence and duration of menstrual disturbances in young athletes engaged in intensive training have been reviewed.

With few exceptions, menarche is delayed in athletes. Moreover, female athletes engaged in intensive training show an increased frequency of menstrual irregularities. The data dealing with this issue have not been convincingly researched. Factors that could influence the time of menarche, such as genetic influences or nutritional status, must be systematically controlled for meaningful conclusions to be drawn.

Also, the skeletal maturation of young male athletes engaged in cycling, rowing and ice hockey was followed from 12 to 15 years by Kotulam et al., who concluded that regular physical activity has no effects on the growth of young male athletes.

The question of athletic potential has been addressed. The response of a given athlete to a particular training regimen is due to an inherited genotype. Only approximately 30% of the maximal oxygen uptake (VO₂ max) and maximal force and power of top class competitors can be accounted for by training.

Young athletes undergoing vigorous training were found to be taller and to have less body fat and higher VO₂ max than sedentary controls. In another study, 34 boys aged between 12 and 16 years old engaged in competitive middle and long distance running were compared with 56 controls not undergoing intensive training. The runners had been training for 2 to 5 years, and had less body fat and lower resting heart rates. Statistically significant differences were only achieved between the 16 year olds. The young runners in this study also had larger heart volumes.
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and a higher VO₂ max relative to body weight and respiratory capacity.

In another study, the effects of endurance and sprint training were studied on the vastus lateralis muscles of boys aged 16 and 17 years18. Endurance training resulted in a significant increase to type I and IIA fibre areas, together with increased activity of some of the enzymes of the Kreb's cycle. On the other hand, sprint-trained boys showed a significant increase in the activity of glycolytic enzymes.

Fewer controlled studies have dealt with the trainability of muscular strength in children. Pre- and post-pubertal children of both sexes can significantly increase their muscular strength by resistance training19,20. The traditional view19 in this respect is that the potential to develop strength is not at its maximum before puberty. Nevertheless, according to Pfeiffer and Francis, pre-pubertal children are likely to have a greater muscular strength trainability than older age groups21. When interpreting the effects of a strength training programme, one should consider that the natural increase in strength in boys reaches its maximum only approximately 1 year after the growth spurt, while in girls this occurs during the period of growth spurt itself22.

Intensive training may result in staleness. There have been a number of reports of a fatigue syndrome in top class athletes. However, no controlled studies have been performed. Some possible important contributing factors to fatigue include an increased predisposition to viral infections, fatigue from over-training or combination of physical and psychological fatigue analogous to the 'burn out syndrome' reported in other contexts10,23,24. Keast et al. have stated that sports mediated immune response alterations may play a major role in determining increased susceptibility to infections25.

Sports injuries

Some epidemiological studies have shown that between 3% and 11% of school-aged children are injured each year due to sports activity26,27. Physical characteristics can play a major role both in the choice of sport and on the pattern of injuries28. For example, joint laxity may result in a child's choice of gymnastics, but is associated with recurrent sprains and dislocations29.

During the growth spurt, adolescents are particularly vulnerable to injuries, partially due to imbalance in strength and flexibility30. The huge increases in participation, training and competition have resulted in children incurring injuries previously seen almost exclusively in adults30,31.

The skeletal system is extremely plastic in children and shows pronounced adaptive changes to intensive sports training32. The long-term effects on bone of participating in intensive training during the period of growth and development are still obscure. Low-intensity training can stimulate bone length, but high intensity training may inhibit it33,34.

Sports injuries could result in damage to the growth mechanisms with subsequent life-lasting damage35. Physiological repetitive loading is indeed beneficial36 but excessive efforts may result in serious injury of the weight-bearing joint surfaces37. Due to the presence of growing cartilage, and the process of growth itself, the skeletal system of a young athlete is more prone to specific types of injuries38. In addition, ligaments in children are two to five times stronger than the cartilage and bone of the epiphysial plate to which they are attached39,40. This results in a greater likelihood of fracture of the epiphysial-metaphysial junction rather than the ligamentous tears seen in adults.

Over-use injuries are characterized by chronic inflammation due to repeated microtrauma. Young athletes may develop one or more of a group of over-use injuries referred to as osteochondroses41. In some instances, an osteochondrosis involves degeneration of the centre of ossification where a major tendon attaches to the bone (an apophysis). Common sites are the posterior aspect of the calcaneus (Sever's disease), the tibial tubercle (Osgood-Schlatter disease), and the lower pole of the patella (Sinding-Larson-Johansson syndrome). The small carpal and tarsal bones may also be affected. Young athletes are therefore at risk of developing stress lesions to these susceptible growth areas. In childhood, compression stress fractures occur more commonly than the oblique type seen in adults42,43. Endurance training regimens are probably responsible for at least 60% of all over-use injuries sustained38 and could be avoided by appropriate changes in training.

In case of injury, the first therapeutic measure is rest44. At high performance level, it is important to know whether an alteration of training regimen after an injury can maintain fitness and ensure rapid healing. Very little research has been performed in this area, although in one study that replaced endurance running with endurance cycling for 4 weeks it was observed that maximal aerobic power and submaximal running performance for moderately trained women runners was maintained45.

Psychological effects

Young competitors undergo increased stress and anxiety due to competition46, the outcome of which can be influenced by parents47, potentially leading to a greater incidence of aggression in the young athletes48. These concerns have led to the extreme position of calling for a complete ban on high level competition in pre-adolescence because of the possible long term deleterious effects48. Detailed reviews of the psychological effects of intensive training on young athletes have recently been published49,50.

Conclusions

The physiological responses to training in children appear to be similar to those found in adults and, in the short term at least, seem beneficial. Definitive statements about the effects of intensive training on young athletes cannot yet be made. However, concerns about the physical and psychological injury remain, and it is likely that the age of the child and the particular sport should influence the type and intensity of training.
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