Overuse Injuries in Young Athletes: Cause and Prevention

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SUMMARY

THE FREQUENCY OF OVERUSE INJURIES IN CHILDREN HAS INCREASED IN RECENT YEARS. INCREASED INTEREST IN SPORTS AS WELL AS THE INCREASE IN SPORTS SPECIALIZATION BY CHILDREN IS ONE CAUSE. EXTRINSIC AND INTRINSIC FACTORS PREDISPOSE AN INDIVIDUAL TO OVERUSE INJURIES, BUT ONE SYSTEMATIC CAUSE IS IMPROPER TRAINING. OVERUSE INJURIES RESULT FROM REPEATED SUBMAXIMAL STRESS FOLLOWED BY INADEQUATE RECOVERY. CHILDREN INCUR SPECIFIC OVERUSE INJURIES AS THE RESULT OF GROWTH. STRATEGIES FOR PREVENTING OVERUSE INJURIES INCLUDE (A) THE USE OF VARIED PRACTICE TO REDUCE JOINT STRESS AND ENHANCE LEARNING, (B) PLANNED REST, (C) GRADUAL PROGRESSION, AND (D) CROSS-TRAINING.

INTRODUCTION

The practice of athletics in the United States has changed significantly in the last 30 years (25). Competitive seasons last longer, and athletes often practice all year for one sport. The multisport athlete is almost a thing of the past, as coaches apply intense pressure on athletes to specialize in one sport. Even Division III collegiate athletes now have a nontraditional season, playing softball in the fall or field hockey in the spring. Commensurate with this trend is a dramatic increase in organized competitive athletics for youth (11). The number of additional youth involved in sport is difficult to measure, but one estimate suggests that as many as 35 million American youth are involved in sports every year. Moreover, DiFiori has suggested that the extent of athletic participation is more intense (10).

The American Academy of Pediatrics has indicated that there appears to be increasing numbers of children who specialize in sport at an early age and train all year for that sport (5). For example, articles in the *New York Times* reported on a small town in Minnesota where the basketball coach wanted to start a "traveling squad" for second graders (3). Parents hire private coaches for their Little League players (13). These parents believe that improved batting makes their children better applicants for college. There are literally thousands of club teams playing an inordinate number of competitions a year. In San Diego alone, there are more than 125 baseball teams for children ages 10 and younger, many playing 80 games a year, far more than most college teams. The prevailing thought is that if children do not specialize by the eighth grade, then they are not prepared for higher-level competition.

Moreover, the reduction of physical education in the schools combined with the health concerns of children has motivated parents to create sports programs for their own children, often developing elaborate programs with extensive competition (18). Unfortunately, coaches in such programs often have minimal training. Certification programs for youth sport coaches often are cursory at best. In fact, certification is not required in many locales. There is concern that we place our most vulnerable individuals (children) with the least-trained coaches.

The increase in organized competitive athletics for youth does not come without an increased risk of injury. The risk of injury has always been part of athletics, and Pecina and Bojanic have argued that organized sports were no more dangerous than free play (17). However, children rarely suffer overuse injuries when they control their own activity (10). Overuse injuries, such as stress fractures and patellofemoral stress syndrome, have become rather commonplace in children (17). Studies show that anywhere from 30% to 60% of injuries to children are the result of overuse (2,9,26).

OVERUSE INJURIES

The common cause of overuse injuries is repetitive submaximal loading (27). Overuse injuries occur when an individual undergoes repetitive stress (such as in throwing, running, and swimming) followed by insufficient rest. The typical response to training is

KEY WORDS:
youth; specialization; overuse; injury prevention

adaptation. Muscles, tendons, and ligaments adapt to the repeated stress of activity by getting stronger. But when body tissues are presented with too much stress, too little recovery time, or both, the result is just the opposite. The body's ability to recover is overwhelmed. Instead of a stronger body, we get a weaker, injured one (17).

Overuse injuries are pervasive, occurring to tendons, bursa, cartilage, bone, and especially the musculotendinous component (17). Stress fractures to the tibia and bones of the foot are the result of overuse. Tennis elbow, osteochondroses, Little League elbow, and breaststroker's knee are all overuse injuries. Because overuse injuries are not acute injuries related to trauma, their diagnosis is difficult, and they require proper medical attention (10).

The causes of overuse injury are multifactorial. The predisposing factors (Table 1) that lead to overuse injuries are commonly described as either intrinsic (internal to the individual) or extrinsic (external to the individual). We often have less control over intrinsic factors than extrinsic factors. For example, an individual may appear to have the improper anatomical alignment to perform a specific sport or activity, but coaches would be hard pressed to deny participation based on knee alignment.

CHILDREN AND OVERUSE

The fact that children are growing is the key factor that separates young athletes from mature athletes. There are constant changes in body weight, height, and muscle mass. Growing bones are more porous but, luckily, they tend to heal quickly (17). Growth cartilage is one of the most important differences between the growing and the immature skeleton. Growth cartilage is present at the growth plate (epiphysis) as well as at the musculotendinous insertion. Growth cartilage is particularly vulnerable to the stress of repeated microtraumas. Little League elbow (medial epicondyle of humerus) and Little League shoulder (proximal shoulder) are both overuse injuries to the epiphyseal growth cartilage (17). Growth for all tissues is not linear. For instance, the musculotendinous unit may develop faster than the bone to which it is attached. Such a condition makes the growth cartilage at this junction more susceptible. Osgood-Schlatter disease (insertion of quadriceps into the tibia) and Sever's disease (insertion of Achilles tendon into the heel) are 2 examples of overuse injuries to the musculotendinous insertion. Clearly, children are at risk of specific overuse injuries related to growth.

PREVENTION OF OVERUSE INJURIES

Since the latter half of the 20th century, considerable progress has been made to improve the quality of training (25). Coaches, trainers, and athletes have devised numerous, creative ways to train. Schools and communities compete to provide the best fitness and athletic facilities. Periodized training has become popular, and the variety of training equipment is superb. Summer training camps abound, attracting prospective athletes with high-profile coaches and athletes. Access to training facilities is at an all time high. The prevailing thought seems to be "more is better."

But more is not always better, as human bodies can only withstand so much stress. One of the basic problems is that exercise leaders and coaches often pay less attention to the other side of training, recovery (16). The focus of prevention should be on those factors that we can control. Fortunately, many overuse injuries can be prevented. In fact, the American College of Sports Medicine has suggested that about 50% of overuse injuries in children and adolescents can be prevented (1). Of all the extrinsic factors, improper training methods appear to be the most frequent cause of overuse injuries (17). Prevention must start with a careful look at coaching and training methods to bring about the desired result without injury. A careful examination of daily practices as well as an assessment of organizing practice over time is one place to start.

THE WARM-UP

Regardless of the sport, all workouts and practices should be preceded by a warm-up. In fact, warming up before athletic competition or practice is probably the most common injury prevention technique used in sport. The classic study by Safran et al. (19) in 1988 showed that muscles that were warmed by prestimulation were more resistant to muscle tears than muscles that had not been previously stimulated. Warming muscles by repeated contractions helped prevent muscle tears.

Table 1
Predisposing factors and overuse injuries

Intrinsic factors	Extrinsic factors
Anatomic malalignment	Improper training methods
Prior injury	Poor technique
Poor conditioning	Improper surface for practice and competition
Growth	Excessive pressure from peers, coaches, and parents
Menstrual dysfunction (irregular or absent menses)	Inappropriate equipment—footwear being the most important

Increasing the temperature of muscles has several physiological benefits (Table 2), including improving the speed of muscle contraction and relaxation. Preliminary exercise dilates capillary beds and increases cardiac output (6). General warm-up and related warm-up are the 2 most common forms of pre-event activity. General warm-up includes such activities as calisthenics and jogging, whereas related warm-up involves participating in the exact activities one intends to perform while playing. General warm-up often precludes related warm-up, but it is important that athletes use the exact same muscles they will use while practicing or playing. Related warm-up is generally preferred over general warm-up for this reason. Warm-up should last a minimum of 10 minutes, since it takes that long for muscle temperature to reach a steady state (6). Start the warm-up slowly and progressively increase the intensity. Warming up should not be fatiguing. Remember that not everyone is in the same state of fitness and warm-up should be planned accordingly. After warm-up, there should be a brief period (3–5 minutes) recovery before practice starts.

ORGANIZING PRACTICE TO REDUCE OVERUSE INJURY WHILE IMPROVING PERFORMANCE

Practice is the key to improved sport performance. In fact, practice is usually considered the single most important factor to learn sport skills (12). Because overuse injuries are normally the result of high repetition activities, the first stumbling block is how to organize practice without excess repetition. Can sport (motor) skills be taught without excessive drilling? Providing sufficient practice time, yet not so much that the athlete acquires an overuse injury, is a daunting task. I recently visited a local tennis club, where a former top-rated player was giving lessons to adolescents. He set up ball machines and had players hit 100 forehands followed by 100 backhands. He then had them hit 50 serves in a row. The pro walked around providing feedback and instruction. The players did improve their performance but became quite fatigued and obviously bored. It wasn't fun to watch and I'm sure it wasn't fun to do. On the surface, one might think that this was good instruction; brand new ball machines, nice courts, and an enthusiastic teacher seem like a good idea. But where's the fun, the motivation, the decision-making? Does anyone ever hit 100 backhands in a row while playing? Further, excess repetitions are a recipe for overuse. Research in motor learning suggests ways that learning is enhanced while limiting endless repetition. In fact, teaching by nonstop repetitions may be an inferior learning technique.

Vary practice to enhance learning and reduce overuse. Let's take the example of our young tennis players who are working on backhands, forehands, and volleys. Now let's say that as the teacher you're going to devote 30 minutes to stroke work. How you distribute this 30 minutes of time spent performing the skill will affect learning as well as joint stress. The literature in motor learning suggests that this distribution is a question of mass vs distributed practice (22). Massed practice means to run the work periods very closely together with little or no rest. Distributed practice involves work periods interspersed with short rest intervals. Schmidt and Lee suggest that distributed practice is better for performance as well as learning. In fact, they even suggest that longer rest periods are better than shorter ones (22). An important factor during practice is fatigue. Fatigue increases muscle strain, reducing the ability of the muscle to absorb energy (14). Distributed practice (like interval training) tends to reduce fatigue, allowing muscle to absorb force and protect joints more easily. Distributing learning activities by interspersing rest with work is great for learning and injury prevention.

A second question regarding practice is the sequencing of drills. In our example, the players hit all forehands, followed by backhands, etc. This practice technique is often labeled as blocked practice. Hitting numerous backhands in a row is stressful whether it's massed or distributed, especially if the player is young and not biomechanically correct. Random practice is just the opposite, mixing up forehands, backhands, and volleys. Random practice is an example of contextual interference, first presented in a study in 1979 (23). Schmidt and Lee (22) report that the immediate acquisition of performance is better when practice is presented in a blocked fashion. However, retention of the motor task is better with random practice. When asked to repeat the task(s) at a later date, subjects who practiced in a random fashion were superior in performance.

The classic report by Schmidt in 1975 supports varying practice to bring about the desired result. Schema theory suggests that people develop generalized motor programs. In fact,

Table 2
Benefits of warm-up

Muscles contract faster
Muscles relax faster
Economy of movement is improved
Metabolism is enhanced because of the increased temperature of muscle tissue
Muscle blood flow is increased
Provides a last minute practice session
Athletes prepared psychologically for performance

Schmidt's "schema Theory" suggested that people will learn more quickly if they practice a task in a variety of situations, like throwing a ball but different distances each time. Moreover, practice that lacks variety is less informative to the learner (20). Wulf (28) has extensively studied schema theory and concluded that varying practice works well with children.

Further support of the variation of practice has come from "The Games Approach." Martens has suggested that the overemphasis on technical skills as well as excessive use of direct instruction reduce decision making and increase boredom. Martens recommends this approach as an alternative to traditional teaching methods. The games approach involves more specific training, that is, practice is more game like. Martens asks the question if having a baseball player hit 50 balls at a time prepares them for a game when they only have 3 strikes. Martens argues that the games approach is very motivating and that practice may make more sense when the athlete connects practice with play (15).

Because the cause of overuse injuries is excessive repetition without recovery, it would appear that conventional teaching methods, involving repeated drills of the same activity, is unwarranted. A practice session that involves variety allows more time for recovery, less fatigue, and produces desirable learning effects. Indeed, practice that is fun and uses game-like activities may also encourage continued participation.

MEASURE PROGRESSION TO REDUCE OVERUSE INJURY

Coaches, teachers, and trainers should be able to quantify any practice. Quantifying workouts provides leaders with a method of measuring progression. Track and swim coaches can count distance, strength coaches can count repetitions and tonnage, and tennis coaches can count time on task. Regardless of the sport or training technique, quantification is possible and necessary.

Gradual progression. Gradual progression is one of the most important principles in the prevention of overuse injuries. The most frequent training error is a rapid change in volume and intensity. Because the goal of training is improved performance, a training program that creates injuries (that take considerable time to heal) seems poorly planned. Interestingly, this is often not the coach's fault. One of our coaches was recently surprised when he found one of his soccer team members running on the treadmill at 10:00 p.m. Normally, this would be fine, but the soccer preseason was in full swing. The athlete was concerned about her fitness and decided to do some extra work. Athletes are often highly motivated to get in shape and tend to be impatient. This is when coaches and trainers need to have a firm hand, to know when to stop or slow down.

One common suggestion is the 10% rule (9,10). For example, if a swimmer is doing 3,000 yards 1 week, they should do no more than 3,300 yards the next week. Although this is a convenient guideline, not everyone can withstand a 10% increase and such changes may need adjustment. How much yardage is enough? In one thorough review of overuse injuries, the authors suggest that "mileage mania" is the cause of many overuse injuries, especially stress fractures (17). Coaches must continuously monitor their athletes for soreness, performance, lethargy, and boredom. When athletes are excessively sore and performing badly, more exercise is often not the answer.

Changing surfaces. Changing surfaces is often problematic for athletes. Let's say a group of runners has been training on a long distance dirt path and move to an artificial track surface. Although such a training strategy may be recommended, a typical error is that athletes are often asked to repeat the same workout performed on their familiar surface. Any change in surface will place additional demands on the musculoskeletal system. Running on a beach might be fun but a bad idea if athletes are required to run their normal distance. When changing surfaces, athletes need to reduce the amount of work until they adapt.

Periodized training. Periodized training is a powerful strategy to improve performance and reduce overuse injury. Periodization requires planning with specific seasonal as well as annual goals. Periodization plans involve a gradual progression in activity designed for the athlete to peak for specific activities. Moreover, periodization involves planned rest, whether annually or weekly. Easy workouts are planned to follow hard workouts. After peak periods of training, the plan calls for athletes to back off, possibly cross train, to get away from their primary sport or activity. Planned rest allows for full recovery and adaptation (4).

SPECIALIZATION

The role of early specialization remains a source of controversy in exercise science. Unfortunately, the improbability of reaching championship performance does not seem to discourage many children (and their parents) from aspiring to be Olympic champions or NBA players. Scores of children lose out on the diversified development gained by participating in a variety of sports. The American Academy of Pediatrics has stated that "Young athletes who specialize in just one sport may be denied the benefits of varied activity while facing additional physical, physiologic, and psychologic demands from intense training and competition" (8).

Clearly, one question we need to ask is whether the increased interest in specialization and competition reduces physical activity in later life. A common goal stated to support youth sport programs is the promotion of lifelong physical activity. We now frequently read about overtraining, staleness, fatigue, burnout, and overuse injuries. There are a number of burnout theories, but the common theme is overtraining (7,21,24). This overtraining

syndrome is often defined as a succession of psychological and physiological changes that result in reduced performance (5). Burnout has been well described in the literature for adult athletes. Simply put, athletes who burn out tend to quit, some never to return. Far less is known about burnout in children, especially the effects of sport specialization. In a recent review, Brenner suggests that burnout may have a detrimental effect on lifelong physical activity (5). Does sport specialization for children promote lifelong activity? Because sport specialization is a rather recent phenomenon, not enough data exist to answer this question.

Leaders of children's sports are often well meaning, but occasionally ill informed. Coaching practices are often based on adult models, historical precedence, and anecdotes. Coaches and leaders of children's sports need basic knowledge of growth and development, pedagogy, and exercise science. Further, they need to apply this information to youth sport.

RECOMMENDATIONS TO REDUCE OVERUSE INJURY

- When teaching sport skills, reduce endless repetitions of the same task.
- Teach motor skills in a distributed manner, interspersing frequent rest periods with work periods.
- Use random practice, mixing up activities so that the same activity is not repeated excessively.
- Use frequent games to vary practice and enhance motivation.
- Keep workouts interesting and age-appropriate.
- Gradually increase progression of the workload.
- Monitor athletes for fatigue, soreness, and general apathy.
- Take care to reduce workload when changing surfaces.
- Periodize training on a weekly and seasonal basis.
- Take 1–2 days of absolute rest each week.
- Schedule breaks every 2–3 months with a change in activity.
- Encourage children to participate in a variety of sports.■

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