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Overuse injuries in athletes: a perspective

WILLIAM D. STANISH

Nova Scotia Sport Medicine Clinic, Dalhousie University, 5938 University Avenue, Halifax, Nova Scotia, CANADA

ABSTRACT

STANISH, WILLIAM D. Overuse injuries in athletes: a perspective. *Med. Sci. Sports Exerc.*, Vol. 16, No. 1, pp. 1–7, 1984. Injuries secondary to sporting activities have increased significantly in the past decade. Traditional treatment programs for these maladies have frequently failed to meet the physiological expectations of the athlete. Forced rest or immobilization result in predictable musculoskeletal atrophy with impaired function. Furthermore, the rehabilitation process has commonly focused on the management of the acute problem with minor attention to the etiology and pathomechanics of the injury (preventive medicine). Many sports injuries, as a result of overuse, can be avoided by scientific coaching and contemporary sports medicine.

ATHLETIC INJURIES, OVERUSE SYNDROMES, STRESS, REHABILITATION, BIOMECHANICS, ELECTRICITY, ATROPHY

The explosion of fitness and sport-related activities has offered many challenges for the medical practitioner. Prior to the early 1960s, expertise in understanding injuries secondary to sport was in a period of infancy. Most medical attention was directed to the diagnosis and management of the acute injury with minor attention given to the analysis of preventive measures of those disorders. The relative lack of knowledge in preventive medicine in sport science spanned all disciplines including physiology, biomechanics, and biochemistry.

As the number of participants in all sports began to increase enormously during the past two decades, the incidence and prevalance of sport-related injuries also increased significantly. Many epidemiological studies have since documented the trends of injuries in individual athletic activities. Sport scientists and medical practitioners have demonstrated great concern because of this obvious carnage. The curriculum of many schools of physical education have addressed these new medical problems by spawning improved training programs for coaches and sport administrators. Furthermore, medical doctors, distraught by the sheer numbers and complexity of these athletic injuries, have been instrumental in developing sport medicine clinics world wide. These clinics have frequently been characterized by offering most medical and paramedical services concerned with the health care of the athlete.

These are the invited comments of the author which have not been evaluated or processed by the review procedures established by the Editorial Board of *Medicine and Science in Sports and Exercise.*

The spectrum of injuries evaluated daily in any one of the sport medicine facilities is highly varied. Indeed, the vast majority of these maladies are usually injuries to the musculoskeletal structures; the most troublesome problem of the musculoskeletal system is the so-called "overuse injury."

By definition, an overuse injury occurs when a structure is exposed to a repetitive force beyond the abilities of that specific structure to withstand such a force. For example, when the stresses placed on bone or tendon are too great for the stress-absorbing capacity of that bone or tendon, rupture or fracture will result. Fatigue fractures seen commonly in industrial concrete or in commercial aircraft present an identical circumstance to the stress fracture observed in the tibia of a runner.

Similarly, exaggerated psychological stresses placed on the athlete may also trigger breakdown. One can visualize the ideally compensated human organism; athletes functioning in perfect harmony, both physically and psychologically, with the ability to handle exogenous stresses. These stresses are usually managed without overt anxiety or musculoskeletal injury. Indeed, this state of "stress without distress," as suggested by Hans Selye, is a very fine but precarious balance. The exhausted human organism, exposed to further stresses, will commonly decompensate and incur injury.

This manuscript will attempt to offer a simple analysis of overuse injuries within the musculoskeletal system of athletes and it will deliberately avoid addressing the psychological aspects. In addition, this article will offer some personal perspectives on these most ubiquitous diseases.

STATING THE PROBLEM

With the new-found interest in collective health and well-being, many more North Americans are involved in competitive and recreational activities than ever before. It has been estimated that up to 20% of our population is currently jogging or running, which constitutes 40 million runners in the United States and a further 4 million in Canada. In addition to running, a wide variety of sport activities have attracted the fancy of adults of all ages. Traditionally, athletic clubs were the bastions of the elite athlete. Today, however, those who remain inactive are in the vast minority. Racquet clubs, weight-training facilities, running tracks, etc., are now as much a part of the community as schools and shopping centers. This health awareness is not restricted to adults, as children and teens are becoming more involved in intramural and other forms of competitive athletics at younger ages.

While at first glance one would suspect that all this athletic endeavour would have increased our state of physical health, the physicians are now treating an increasing number of people who, by most contemporary standards, would be considered quite healthy. However, due to their own zealousness, they have incurred certain types of injuries. As stated previously, these are usually injuries of overuse.

The size of this fitness epidemic, though difficult to document, may well be astonishing. Clement et al. (4) reported 1650 injuries in runners collected by personal experience in only 2 yr. Of this large group, 40% of the injured athletes were women. Children are as susceptible as adults to these problems. Statistics show that 20 million children, between the ages of 6 and 16, are involved in organized recreational programs in the United States (15). For example, swimmers are doing 20,000 m per day; 6-year-olds are competing in full marathons; and tennis camps for children are held 8 hours a day, 5 days a week. Adams (1) found medial epicondylar elbow injuries in 76 of 80 pitchers at the Little League level. Dominguez (6) found an almost 50% incidence of shoulder pain in swimmers not yet skeletally mature. While intuitively one may assume children to be less susceptible to these "overuse syndromes" than adults, the structural laxity of the immature athlete and the open epiphyseal plates may actually render him/her more susceptible to this type of repetitive trauma. The possibility of premature closure of the epiphysis makes one realize the potential for long-term disability in this age group.

Finally, it should be realized that while the numbers of active adults is presently large, it is possible and indeed probable that these numbers will continue to increase with time. Young adults and children who remain active will expand current ranks, soon to be followed by their offspring, who, encouraged by the role model of their parents, will likewise become active. The situation will not disappear on its own.

In order to remedy the problem, one must address the etiologies. In our scheme of analysis, we simply divide etiological factors into two fundamental groups—intrinsic and extrinsic. The intrinsic causes are defects in the genotype of the athlete. Although each of us may wish to compete, we may not possess the necessary faculties or equipment to do so. Extrinsic factors include all other variables from equipment to coaching which may affect the athlete and his/her performance.

The most obvious of the intrinsic problems is mechanical derangement or malalignment. While, for the most part, modest anatomical imperfections seen in athletes are easily tolerated in day-to-day activities, an analysis will readily demonstrate the increased demand on the human body produced by sporting activities. For example, an average 68-kg man will, at a walking pace (with a 76-cm stride) take 2110 steps in 1.6 km. By force-plate analysis, the impact will constitute 80% body weight per step, for an impact load of 115,316 kg. By increasing his pace to a run (stride length 107 cm), the total impact load increases to 200,000 kg, an increase of more than 73% (16). The cumulative effect of this increase over 80–96 km per week is awesome.

The vast majority of malalignment problems affect the lower extremities and no anatomical level is exempt from this problem. Femoral antiversion, which begins in the neonate at 35–40°, gradually decreases in the first 8 years of life to assume the usual adult attitude of about 15°. Persistence of the less-mature positioning of the femoral neck leads to the problem of intoeing seen so commonly in pediatric clinics. With time, the patient corrects the problem with a compensatory deformity at a lower level, often external tibial torsion and/or hyperpronation of the foot.

Malalignment at the knee can be uniplaner (i.e., valgus, varus, or recurvatum) or rotational. Any shift of the weight-bearing axis from its normal position through the anatomic center of the knee results in excessive loading of one of the knee compartments. When such an anatomical aberration occurs, the possibility of early degenerative arthritis must always be borne in mind. As well, soft-tissue injury about the knee can occur when skeletal malalignment pre-exists. Disruptions of the medial or lateral meniscus, irritation of the iliotibial band, and more obscure diagnosis within the knee synovium have all been linked to knee malalignments.

Abnormalities of the patella and the patellofemoral joint are definitely important intrinsic factors of overuse injuries. In the series of Clement et al. (4), almost 30% of all runners suffered with patellofemoral pain. The patella itself can be misshapen (bipartite), too small, or too high (patella alta). The femoral trochlea may likewise be too shallow to accommodate the patella or may be improperly shaped, resulting in loss of joint harmony and congruency. Imbalance of the quadricep mechanism, with overdevelopment of the vastus lateralis, perhaps with atrophy of the vastus medialis, can lead to improper tracking of the patella. Furthermore, tightness of the lateral retinacular structures can produce similar problems. In addition, the angle between the quadricep mechanism, the patella, and the insertion of the patellar tendon on the tibia (the so-called Q-angle) may be excessive and, therefore, trigger abnormal gliding of the patella. This may manifest with retropatellar pain.

Further deformity may be noted in the foot and ankle. In the minds of some, the subtalar joint is probably the keystone to normal foot mechanics. During running, this joint allows the foot to migrate from slight inversion at heel strike through a period of rapid pronation only to return to a supinated attitude for push-off (11). Excessive supination or, more commonly, excessive pronation of the foot can lead to a myriad of problems extending from the lumbar spine to the forefoot. Examination of this movement must be performed with the patient standing, supine, and prone to fully appreciate all the subtleties involved. Malalignment of the hindfoot can lead to a problem of the patellofemoral joint (chondromalacia patella), the hindfoot (plantar fasciitis), and the forefoot (metatarsalgia).

Finally, the forefoot must be assessed. Residual metatarsus adductus, hallux valgus or varus, and the length of metatarsals must be evaluated. Valgus or varus deformity of the first metatarsal phalangeal joint can cause pain and disability. Factors that cause the transverse metatarsal arch to collapse also produce circumstances which result in metatarsalgia. This can occur because of tightness of the interossei muscles or because of inappropriate footwear.

A slightly less documented and certainly less obvious intrinsic factor is the strength and flexibility of the musculotendinous unit. Stretching exercises increase the range of motion about the joint, and various techniques have been used over the years by dancers and gymnasts to facilitate a greater freedom of movement. Many techniques for increasing the range of the musculotendinous unit have been described (5) and various investigators have suggested the beneficial effect of that phenomenon (20).

The general level of fitness of the active athlete is another important intrinsic factor in the evaluation of overuse injuries. Hamel et al. (9) cite an increase in the average height of the American child of only 10% compared with a concomitant increase in the average weight of 30%. Many people, caught in the current wave of increased participation in sports, are not physically prepared for the levels of activity at which they begin. While trying to duplicate activity levels of more fit colleagues or attempting to recapture the fitness levels of years gone by, many citizens are attempting too much activity over too brief a span of time.

A final consideration of intrinsic factors involves the child athlete with open epiphyseal plates and actively-growing cartilage on the joint surfaces. Succinctly, these structures include the physis, the articular hyaline cartilage, and the apophysis at the bone-cartilage tendon interface.

Studies conducted in Japan have suggested that excessive exercise loads can cause growth-plate injury and lead to permanent boney deformity (13). Repeated microtrauma to the proximal humerus in the growing skeleton has been suggested as the etiology of Little Leaguers' shoulder (18).

In addition, the articular cartilage itself is more susceptible to shear stresses in the child than in the adult, especially at the elbow, the knee, and the ankle (18). These areas are prime sites for osteochondritis dissecans, a disease which is controversial and still ill-understood. Perhaps, it too will be included in the category of an "overuse disease."

The third focus of cartilagenous susceptibility in the young athlete is the apophyses, most notably at the tibial tubercle and the calcaneus. While tendinitis of the patella and Achilles are uncommon in the growing skeleton, apophysitis in these regions is common. This is, no doubt, a reflection of the relative vulnerability of the rapidly-growing bone-cartilage-tendon interface to injury.

A further feature of the growing athlete, not seen in the adult, is the rapid change in the ratio of bone length to the length of the musculotendinous unit. As the adolescent enters the growth spurt in early to mid-teens, one sees a rapid increase in the height and the length of the long bones. The soft-tissue envelope surrounding the skeleton tends to lag behind the skeletal elongation. This combination leads to an increase in the relative tightness of the muscle-tendinous unit and a corresponding decrease in flexibility (18). This fact is often overlooked in the assessment of the young athlete and could be important in the production of overuse disorders.

There are many extrinsic causes of overuse syndromes. Footwear is becoming more sophisticated, with the sports shoe industry blossoming and expanding enormously. In the past, one's choice in athletic footwear was restricted to size and color; however, presently, the vast selection of shoes, boots, and skates allows the athlete almost a custom fit. Several basic necessities should be incorporated into any shoe used by recreational or competitive runners. These features have been described extensively by James et al. (11). These investigators suggest a firm heel counter to control hindfoot movement combined with a built-in pad for the Achilles tendon. They have suggested that the heel should be flared for stability and beveled to allow ease of plantar flexion. They also point out that while a majority of shoes are made with an in-turned forefoot, this does not follow normal anatomy; therefore, they suggest a straight-last running shoe as being more advisable. Finally, it should be noted that while many athletes choose appropriate footwear correctly, many do not maintain it in adequate condition. The proper shoe may rapidly lose its effectiveness if not kept in satisfactory condition, thus facilitating injury.

Terrain is another important extrinsic consideration for the jogger and runner. As stated previously, the stress absorbed by the human body while running is enormous. While proper footwear can reduce the impact loading considerably, the terrain on which the athlete trains must also be chosen carefully. The optimum running surface should deform sufficiently to help cushion impact yet be firm enough to supply ample stability. Many runners live in the city where the only terrain available is the city street, a less than ideal medium. While the asphalt and tar cover on most roadways has more cushion than concrete, there are associated tradeoffs. First, the incline on the lateral edge of the roadways (built with asphalt) acts to apply uneven valgus-varus stresses to the lower extremity. In addition, there is an increased risk of motor vehicle-athlete confrontation on the highways, which adds considerably to the morbidity of the sport.

Improper skill technique is another important extrinsic factor. In injuries to the upper extremity of the throwing athlete, Jobe (12) points out the problem of "opening up." During this movement, the athlete turns his body while allowing the arm to lag behind. This forces the elbow to descend, resulting in a rapid acceleration through the shoulder, producing excessive force on the rotator cuff. Similar problems can occur with the weight lifter sustaining injuries to the lumbar spine during the hyperextension posturing while lifting.

The methods of training are equally important. A rapid change in training sessions can lead to system failure. One major training error includes excessive duration of the work-out session. Runners often feel that performance directly parallels the distance run. This is not necessarily so. James (11) noted a 29% incidence of excessive mileage in his patients with injury. In addition to duration, intensity can be a significant contributing factor. Runners often experience their first injury when they increase their speed while maintaining the same distance. As mentioned previously, terrain can affect the athlete, especially when combined with changes in training routine, i.e., performing wind sprints on hills.

A final extrinsic consideration is the ill-defined concept of over-training. Participants of a recent round-table discussion (19) uniformly agreed that an accurate and universally-acceptable definition of over-training is not available. However, a definite syndrome does exist. The discussants were able to agree that there was an intensity of training that would put an athlete beyond the critical point and thereafter, training, instead of increasing or enhancing performance, would actually decrease it. This syndrome consists of weight loss, insomnia, anorexia, and frequently, depression. The athlete commonly manifests an increased resting heart rate and a retarded recovery after exertion. Once established, the effects of over-training can take months to resolve.

Fatigue or stress fractures of weight-bearing structures are common. It is indeed interesting to note that amongst all species, stress fractures are noted only in humans, race horses, and greyhounds (17). The common denominator in this group is that these are the only species who train at maximum effort despite pain. The enthusiasm of the human spirit may well be at the root of the overuse and abuse problem.

SOLUTIONS TO THE PROBLEM

The reason for identifying the problem and analyzing it meticulously is in an attempt to control the problem of overuse injuries. There are a large number of healthy, active adults who are disabled and prevented from their favorite activities by painful disorders. The sport medicine scientist and practitioner are duty-bound to find an appropriate solution.

The simplist and most logical approach to the problem of overuse would obviously be rest and abstention from these activities. If the runner has pain after jogging only 6 km, he could be told not to jog. The swimmer with a painful shoulder could be encouraged to stay completely out of the pool. While this may seem like the most direct route, it is flawed in two basic regards. First, the athlete, young or old, will not accept this prescription. They want to, almost need to, participate and, despite what they are told, will return to their sport and rely on other medical counsel. Second, history has dictated the evil effects of inactivity, both physically and psychologically. Mark Twain once pointed out that if he gave up smoking, he may not live any longer, but it would certainly seem like he had. It is incumbent upon the musculoskeletal physician to investigate and determine the etiology and pathomechanics of an injured tissue because only then can a proper and effective rehabilitation program be constructed. The athlete desires to play and the medical community must help him/her do so.

In our clinic, the development of a treatment package is determined by the same type of analysis we employ in determining the cause of the problem; that is, analysis of the intrinsic and extrinsic factors. The most common intrinsic problem is structural malalignment. As noted previously, this anatomical abnormality may exist anywhere, from the lumbar spine to the forefoot, and careful identification of these features is essential to a satisfactory and successful treatment. The majority of malalignment problems are minor and supple. That is to say, with applied external forces, these irregularities can be corrected or reduced to a tolerable level. One of the most common of this group of structural malalignments is supple flat feet, which rotate in an exaggerated position of pronation on weight bearing. Scientifically measured and constructed, corrective orthotics can normalize stresses immediately and render the competitor more functional. Some malalignments, however, resist these conservative measures and, on occasion, surgical correction is essential. As noted by Clement et al. (4), chondromalacia patella is a major problem in the running community. Our clinic is a proponent of a minor surgical procedure on the patella support mechanism, namely, the lateral retinacular release, allowing restoration of balance on the patellofemoral joint. To reiterate, careful preoperative assessment of all extrinsic and intrinsic factors is mandatory before embarking on this relatively aggressive route.

Although difficult to document, many investigators believe that excessive inelasticity of the musculotendinous unit is a significant cause of morbidity. Fowler (17) states that the tight rotator cuff and shoulder muscular imbalance are major contributors to the problem of "swimmer's shoulder." Recommended are vigorous stretching and strengthening programs for these swimmers. Fowler also states that for the shoulder, ballistic exercises, such as swinging weighted clubs, are very useful. In dealing with the lower extremity, many researchers (5,20), myself included, believe that ballistic stretching can be dangerous, and recommend other techniques which follow neurophysiological principles more closely. Regardless of technique, extending the range of motion of the musculotendinous unit is empirically beneficial in alleviating many overuse problems, from chondromalacia patella to the snapping-hip problem. However, in the future, carefully controlled clinical and basic science research will be needed to better define the value of flexibility training.

The general fitness of the athlete should be assessed and documented accurately. There are many parameters which must be evaluated and monitored. Aerobic vs anaerobic capacity, submaximal heart rate, flexibility, strength/power, and body morphology are all important factors in the evaluation of fitness. While the term "out of shape" is generally reserved for the neophyte athlete, many who have done extensive training are still deficient in certain categories. The athlete must be fully assessed and counselled as to a custom-made fitness program incorporating and merging the aforementioned categories. The program that results may include alterations in training routine, diet, or complementary exercises to maximize injury-free performance.

The child, skeletally immature, is a difficult problem. While we have identified possible intrinsic vulnerability in the epiphyseal plate and the apophysis, one could hardly treat these physiological features directly. Most often, the physician is forced to simply accept the fact that the young athlete will play with mild discomfort; however, the patient and the parent must be educated to understand that the symptoms are indeed self-limiting. For this to be achieved, one must be certain of the diagnosis. It would be a tragedy to misdiagnose an osteogenic sarcoma in the tibia of an adolescent because his/her symptoms closely resembled Osgood-Schlatter's disease. Once certain of the benign, self-limiting nature of the problem, the physician encourages most young athletes to understand the difference between hurting and harming, and personally monitors the ideal level of activity for them.

Extrinsic factors are often easier to identify and alleviate. For example, poorly designed or ill-fitting footwear can be a triggering factor in overuse injuries. The athlete should always bring his/her footwear to the physical assessment. The physician must understand basic requirements of the shoe (boot or skate) in question as briefly discussed previously. The shoe must also be examined for excessive and localized wear patterns which may offer clues to other related factors. Finally, the general condition of the foot apparel should be assessed and emphasized. Gait analysis, running and walking, with high-speed filming has proved most helpful in our clinic. When one considers the forces generated at the foot-ground interface, it is easy to comprehend the necessity of proper footwear.

Terrain and, in general, all training surfaces are more difficult to control. While new shoes or boots can be purchased anywhere, altering one's physical surroundings is much more difficult. Often, the athlete is unaware of the proper or optimum surfaces on which to enjoy his/her sport. While sensible surfaces are readily available, athletes may, through lack of knowledge, choose their terrain incorrectly. A thorough consultation and explanation from the specialist to the athlete (and community) is therefore mandatory.

Training techniques should also be evaluated. While proper coaching might avoid many overuse injuries, most recreational athletes do not have access to adequate supervision. Various errors must be ferreted out and rectified, for the athlete may be making simple errors in technique or program design. The ideal duration and intensity of training for each age and sport is not thoroughly documented. The quest for such information is fundamental to avoiding over-stress syndromes. Is 96 km per week better than 48 km in anticipation of achieving the same performance? How should the distance be divided? Should pitchers throw between games and if so, for what duration and how hard? How useful are wind sprints or interval training? While the answers to these and other questions are needed, one can still help our athletes identify gross errors in training technique while offering accurate solutions to the problem without hampering performance.

A word must be said for the newly-recognized problem of the over-trained athlete. While the problem only affects a small percentage of the general population of athletes, it is a serious issue and one which may shorten or end the career of a potential athlete, elite or otherwise. In the future, we must strive to better understand and intercept this syndrome. Early markers, such as increased resting heart rate, wide fluctuations in body weight, and general attitudes toward training are currently being evaluated. In addition, biochemical aberrations and hemoglobin levels may be signals to the syndrome. These areas are under investigation. Optimally, we will soon be able to identify and measure early warning signals to alert coaches and athletes. Finally, it is a delusion to think that enforced rest and immobility is the panacea it would seem to be for the overuse phenomenon. Indeed, it may well induce its own set of problems. "Form follows function" must be an important dictum to the sports physician. The earliest response to rest is atrophy, as documented by Hippocrates (10). If not used, muscle bulk is lost rapidly and may never normalize. The important aerobic enzyme systems, endogenous to striated muscle integrity, degenerate rapidly when not used (21). While supplanting an injured athlete's usual form of exercise with an alternate type of aerobic activity may seem a reasonable means of avoiding this phenomenon, such is not the case. While maximum oxidative capacity is, to a certain extent, dependent on cardiorespiratory performance, the local effect of exercise on muscle must not be forgotten. The runner who swims or the swimmer who cycles does not maintain aerobic enzyme systems in the resting muscle necessary for optimum sport-specific fitness. Researchers, including those of our own laboratory, have demonstrated that oxidative enzyme systems, the basis for aerobic activity at the cellular level, can be maintained by faradic stimulation of muscle (21). Perhaps, such external stimulation of muscle will not only be an important part of the rehabilitation program, but will be employed regularly as a modality designed to achieve supramaximal performance.

It should also be remembered that while their metabolic activity is much lower than muscle, tendon and ligament are not inert tissues. The studies of Yasuda and Fukata (23) showed many years ago that most mesodermal tissues exhibited electrical activity and that electrical stimulation applied to bone could increase bone mass. It is believed that this electrical phenomenon is important in maintaining the integrity of ligament and tendon. Furthermore, this normal state of electrical balance can only be achieved with regularly applied stresses. Rest and inactivity following injury can lead to aberrations of the electrical milieu, resulting in retardation of the healing environment.

RUMINATIONS

All humans, athletic or otherwise, are individuals. Individual, that is, in their intrinsic make-up—body and personality. It is quite natural for people, both children and adults, to explore themselves physically and psychologically in order to gain greater depth of understanding. Basically, that understanding of oneself results in an appreciation of the basic capabilities of self. Only with a firm grasp and understanding of these potentials or limitations can the organism live a satisfying, healthy existence. However, this satisfying and productive life must be predicated on realistic expectations and to live beyond these may lead to break-down of the human structure. Very commonly, in the world of athletics, there is an underlying theme that causes one to push and force beyond the threshold of intrinsic capabilities. This process commonly results in injury, and these injuries, overuse in nature, may vary greatly in severity. Fortunately, most overuse syndromes are reversible, implying that once the stress is terminated and the body is allowed to mend (according to the classical biological laws of healing) no permanent dysfunction will remain. Although normal function may return, there may exist irreversible changes at the cellular level. Collagenous scar within the injured tendon (22) or muscle may render that tissue vulnerable to reinjury. As sport medicine physicians and scientists, we are acutely aware that athletes will continue to force their bodies and minds beyond the limits of compensation. Philosophically, we must accept this fact as a fundamental reality in sport. Our energies must be directed to intercepting these overuse injuries rather than merely discouraging the athlete from further participation. Traditionally, the athletes incurring injuries secondary to over-stress have been immediately stopped in their activity by doctor, parent, or infrequently, the coach. These decisions to terminate the sporting activity were usually without scientific explanation and understanding, and were based more on emotion than reason. Furthermore, the destructive potential of physical inactivity, brought to light in recent years, was not totally appreciated. Hippocrates (10) had stated, ". . .exercise strengthens and inactivity wastes." Frequently, athletes suffering with overuse syndromes would never return to their former level of performance because forced periods of prolonged rest and immobilization produced irreversible tissue deterioration.

The modern quest in the area of sport medicine and science must be to address directly the issue of prevention of overuse injuries. This objective may seem complex, but it is a necessary challenge for the contemporary thinker interested in sport.

The future, brightened by the computer, will allow many disciplines to provide counselling to athletes. Perhaps the athlete, prior to injury, could be classified biomechanically, physiologically, and psychologically, providing each participant with a score. It is conceivable that these score charts, statistically analyzed, will enable each individual to choose a sport which will fulfill his/her expectations while simultaneously offering reduced risks of physical injury. Such a counselling service may even offer the elite athlete a specific training agenda predicated on realistic expectations for levels of performance. If the individual chooses to force beyond these guidelines, then an injury chart could be issued demonstrating the increased risks of injury with increased training time, increased difficulty of skill, etc.

Some experienced coaches at the Olympic level have the ability to identify championship potential in children. Through experience and intuition, these coaches have developed the uncanny ability to analyze the anthropometry, strength/power potential, and mental attitudes of a particular candidate. Synthesizing this information has commonly allowed that elite coach the data necessary to select a potential world champion many years in advance of his/her maturity.

In the future, reproducible scientific data will provide training techniques for each athlete that will markedly reduce overuse injuries. Once the injury has occurred, however, different problems become manifest. Traditional techniques of diagnosis and treatment have proven satisfactory for the inactive citizen or non-athlete, but are less than ideal for the athlete. The injured client is no longer willing to accept "rest" as the cornerstone of his/her treatment program. A sustained growth in the number of specialized sport medicine clinics has increased as predicted, and educational programs for trainers, athletic therapists, physiotherapists, medical doctors, and orthopaedists have flourished. These programs have resulted in improved expertise in the science of sport and sport medicine.

The analysis of the etiology and pathophysiology of these unique injuries cannot be overemphasized. Initially, the treatment of overuse syndromes has and will be directed toward controlling the pain component. This feature of the medical problem (i.e., overuse injuries) is readily ameliorated with pharmaceuticals and physical modalities. However, the major issue, vital to offering a permanent solution to the overuse injury, is in the understanding and correction of underlying mechanical problems related to the injury. Essentially and simplistically, the treatment program must prepare the injured tissue to withstand the stress which triggered the injury initially, realizing that if this objective is not realized, reinjury is predictable. Fundamental to this approach is the task of constructing a treatment program that will render the injured tissue strong enough to withstand forces intrinsic to the sport activity. Also fundamental is an understanding of the forces involved, which in the area of sports biomechanics, have rarely been touched on to date. If the athlete is a recreational player and is blessed with a realistic approach, then the treatment program will be designed to achieve a specific strength for the "performing tissues" of that athlete—obviously then, the elite athlete will require a treatment program of different specificity for his/her tissues (i.e., specific training for specific tasks).

The medical community must reach forward to areas and techniques of expertise that will allow the rapid identification of the athlete at risk. Basically, that thrust is directed towards matching the athlete with a specific sport in hopes of eliminating injury. The future will offer a scientific process for analyzing the new athlete (based on genotype) and identifying a sporting activity that will ideally suit him/her. Future developments may allow scientists to manipulate the phenotype of the person. This may be accomplished with specific training programs (8), hormones (3), or modalities such as electrical stimulation (14). Furthermore, once an overuse injury has occurred, programs of treatment will be based on the ability to control the healing environment. The use of devices capable of direct measurement of tissue strains (personal communication, Malcolm Pope) will afford the opportunity to judge the value of all physical modalities. If ultrasound or early motion actually enhance the return of strength of an injured tendon, then implantable strain gauges will validate this theory. Electrical stimulation for enhanced bone healing (2) has been documented, but research in evaluating the effectiveness of electricity in soft tissue healing and enhancing muscle strength is lacking.

All humans need stress in order to survive. Excessive stress leads to decompensation and injury. Future investigation and research will be designed to render the human host stronger and more able to withstand all varieties of stress. It is unlikely that the stresses of life and sport, physical or psychological, will be lessened. In essence, then, bend or break.

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