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Review Article

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Injury and Disease in Former Collegiate Athletes

Kelly Brooks*

Assistant Professor, Department of Kinesiology, Texas A&M University, USA

Abstract

Athletes undergo vigorous training in order to be successful in their sport. They must participate in more than the recommended amount of daily physical activity to reach a high level of competition. High levels of training can lead to high risk of injury in specific sports, which may lead to future disability and potential risk of chronic disease. The purpose of this review was to examine the incidence of injury in athletes in specific sports. There have been several studies that have tried to establish a link between future disease risk and prior athletic participation. Prior injury may play a role in the development of future disease. This review also examined the relationship between specific sports and future chronic disease risk. Results confirm that more research is needed in order to link injuries in early athletics with future chronic disease risk. Risk of osteoarthritis after joint injury in athletic competition is high in each study analyzed. This review may shed light into the risk carried in specific sports for injury, and serve as a starting place for future research into the risk of chronic disease in athletes with prior injuries.

Keywords: Osteoarthritis; Chronic disease; Athletic injuries; Former athletes

Introduction

It is well documented that cardiorespiratory exercise, as well as muscular strength and endurance exercise, have a positive impact on a person's health [1]. Many positive health benefits arise from moderate intensity exercise including decreased risk of heart disease, cancer, stroke, osteoporosis, and diabetes found in individuals who engage in regular physical activity [1]. The cardiovascular system functions more effectively and the body is better suited to fight disease when it is physically fit [1]. However, there is a point of diminishing returns for these benefits, where overtraining and high- intensity exercise may actually increase risk of traumatic injury, reduce health benefits, and impair immunity due to the extreme stress put on the body [1]. Elite-level athletes undergo training regimens that place them under chronic stress, increasing susceptibility to injuries and overtraining. This review article investigates the incidence of injuries in sport, and future risk of disease in former athletes.

Chronic Disease

Chronic diseases such as heart disease, cancer, stroke, and diabetes are preventable diseases. Physical activity helps in preventing disease through weight control and improved functioning of the cardiovascular system [1]. Elite athletes engage in high intensity exercise for many years. Moderate intensity activity is beneficial in many aspects of health, but there is a point (as activity increases) where health benefits may begin to decline. Exercise at very high intensity increases the risk for musculoskeletal injuries and overtraining [2]. Injuries may make it more difficult for athletes to remain active as they age if the injuries are chronic and severe enough to limit long-term participation in physical activity. There appears to be a consensus among researchers that unless activity is continued, benefits of prior participation in athletics are not maintained [2-7]. Athletes are defined as competitive, collegiate or professional athletes for this review. As athletes become members of the normal population, they contribute to the overall health and sedentary behavior of the United States, sometimes unwillingly through injury. Table 1 outlines the impact of athletic participation on chronic disease.

A study [8] compared incidence of hypertension in former elite athletes and male controls. Subjects had no history of hypertension in 1985. Former elite athletes in endurance or mixed sports (sports including both a power and endurance component) had a lower risk of hypertension than power athletes, while elite athletes with a history in power sports exhibited no benefit with regards to hypertension. Physical activity in later life was also associated with lower risk. Former male athletes were investigated by Sarna et al. [9]. Athletes in endurance and mixed sports had a higher life expectancy and a lower risk for ischemic heart disease and diabetes than those in power sports. Aerobic athletes had slightly higher risk for lower-limb osteoarthritis than the power and mixed sport athletes. Dey et al. [10] examined Cardiovascular Disease (CVD) risk factors in former athletes versus age-matched controls. Specifically, he found that sedentary former athletes had significantly higher mean values for weight, BMI, body fat percentage, total cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides than active former athletes and sedentary non-athletes. His study supported prior research indicating that active athletes had the most favorable levels of CVD risk factors when compared with both the sedentary athletes and non-athletes [2]. The subjects with a high level of total physical activity had favorable CVD risk factors regardless of group. The CVD risk factors of former athletes were more related to the present-day physical activity than to prior athletic participation. Rainey et al. [11] also compared former collegiate athletes with non-athletes, and former athletes were found to have higher levels of physical activity than non-athletes, and were also less likely to have ever smoked cigarettes, both major risk factors for chronic diseases. Anxiety was also reduced in former athletes [12,13] if they maintained activity. Less anxiety may equal less stress, which is another risk factor for CVD.

A study by Pihl et al. [14] examined the impact of previous athleticism on CVD risk factors and found significant differences in CVD risk scores in currently active ex-athletes and recreational exercisers when compared with sedentary controls. The differences in CVD risk factors were related to current physical activity, and were expressed more consistently in men than in women.

Physical activity and exercise have been shown to lower the risk of non-insulin-dependent diabetes (NIDD). In a survey that was part

***Corresponding author:** Kelly Brooks, Assistant Professor, Department of Kinesiology, Texas A&M University, USA, Tel: (361) 825-2670; E-mail: Kelly.Brooks@tamucc.edu

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Disease/Condition	Findings	Sources
CVD	Competing in college athletics not protective unless active lifestyle maintained. Current physical activity more related to risk factors.	2, 7, 20, 33, 35, 37, 42, 66, 67, 70, 74, 81, 90, 101
Hypertension	Benefits seen in endurance athletes only	18, 35
Diabetes	Benefits seen in endurance and mixed sports only- not in power sports Current Pal optima| BMI more related to risk factors.	33, 35, 37, 102
Cancer	Benefits from early activity protective throughout life	13, 89, 100
Osteoarthritis	Increased risk (prematurely) with joint injury and vigorous, high intensity training. Power sports; repetitive, high impact sports (mostly associated with joint injury). Moderate, recreational exercise does not increase risk. Little risk below elite level.	4, 16, 29, 34, 39, 41. 45, 48, 79, 93, 96, 97

Table 1: Impact of Elite Level Athletics on Chronic Diseases.

of a follow-up study, 3940 college alumnae, half of which were former athletes, were asked about medical history [15]. Results showed that physical activity and body mass index (BMI) correlated to a reduced the risk of NIDD, regardless of whether a person was formerly an athlete. Former athletes, current exercisers, and those having an optimal BMI had a reduced risk.

The need for medication in former top-level athletes was studied by Kujala et al. (2003) [16]. The endurance athletes had a lower probability of initiating medication for cardiac insufficiency, coronary heart disease and asthma than the power athletes. The risk of initiating treatment medication for hypertension and diabetes was greater for power athletes compared to endurance athletes. Kujala et al. (1994) [17] compared the prevalence of diabetes, hypertension, and ischemic heart disease between former Finnish elite athletes and controls. Both endurance and mixed-sports former athletes had lower age-adjusted odds ratios (ORs) for all diseases compared to controls. Compared to controls, power athletes had a higher BMI but a lower risk for ischemic heart disease. All subjects with high BMI had an increased risk for disease. Former endurance athletes had the lowest OR for diabetes and ischemic heart disease. Diabetes, hypertension, and ischemic heart disease were less frequent among physically active subjects regardless of previous competitive involvement. Prior research by Kujala et al. (1996) also supported these findings [2,18]. Pihl and Jurimae [19] evaluated cardiovascular disease risk in former athletes according to their weight-change patterns during the post competitive period. Weight gain over 10.0 kg in former athletes was associated with higher body mass index, percentage body fat, skinfold thickness, blood pressure, LDL cholesterol, and triglyceride values. Lower HDL cholesterol and a lower physical working capacity were also observed with the weight gain. Kujala et al. [20] found that former male athletes participating at a young age in either endurance or power sports were more physically active in their post-competition period than controls. Former endurance athletes participated more often in vigorous activity and experienced less coronary heart disease than power athletes. The researchers determined that an aptitude for endurance sports and continued vigorous physical activity may be associated with protection against coronary heart disease. They found that a capacity for power speed events did not give protection against coronary heart disease.

Research has confirmed that former athletes have a lower lifetime occurrence of breast cancer and cancers of the reproductive system [21-23]. In a 15-year follow-up study of 5,398 college alumnae comprised of former college athletes and controls, athletes had a lower risk of breast cancer than non-athletes [23]. Athletic activity during the college and pre-college years was protective against breast cancer throughout the life span. These results are consistent with other investigations [21-23] and there seems to be no difference found with the intensity of physical activity. Research shows that former elite endurance athletes have lower overall morbidity risks in later years compared with controls [20]. Middle-aged male competitive masters runners with a history of long- term training had a lower risk of heart attack than more sedentary men [24]. Former endurance athletes had a lower incidence of coronary heart disease and type 2 diabetes mellitus than age- matched controls [17,20]. Prior research indicates endurance athletes seem to obtain more benefits than power athletes, but were also more likely to maintain activity. Unless activity is maintained, prior participation in competitive athletics does not appear to be protective. It is unclear why endurance athletes seem to maintain activity more often than power athletes. It may be due to the difference in adaptations between anaerobic s. aerobic activity.

Osteoarthritis

Osteoarthritis is a disabling joint disorder characterized by pain, stiffness and degeneration of the joints. The development of premature osteoarthritis of weight-bearing, lower-limb joints is a common adverse effect associated with vigorous physical activity [25-28]. Athletes have been reported to have an increased risk for lower-limb osteoarthritis [26,27,29]. There are many lower-limb injuries obtained through competing in athletics that may accelerate the development of osteoarthritis because joint injuries are strongly associated with an increased risk of developing the disease prematurely [25,26,29]. Participants in power sports that have high risk for joint injuries may have an elevated risk of premature lower-limb osteoarthritis [25,27]. There also appears to be an increased risk of lower limb osteoarthritis in repetitive, high impact sports, such as distance running [25-27]. This risk IS strongly associated with joint injury [25,26]. Koh and Dietz [29] found osteoarthritis of the hip, ankle, and elbow to be caused by repeated loads or a specific traumatic event, supporting prior findings [26-28,30-33]. Knee osteoarthritis appears to be the most common form of osteoarthritis in athletes, and it most often follows a knee injury [26,29].

Two studies confirmed that injury is a risk factor for osteoarthritis. Gelber et al. [33] followed 1,321 athletic patients for 12 years and found that by age 65, those with childhood or adolescent joint injuries had a cumulative incidence of 13.9% of osteoarthritis compared with 6% in those without an injury. The relative risks for developing knee or hip osteoarthritis after an injury were 5.17 and 3.5 respectively. This supported research by Cooper et al. [34] who found knee injury associated with knee osteoarthritis after following patients for five years. Competitive Athletes may be at greater risk of needing hospital care for osteoarthritis of the hip, knee and ankle [25,34]. In a study comparing endurance athletes, mixed sport athletes and power athletes with controls, all athletes had higher incidences of osteoarthritis than healthy subjects [25].

The average age of endurance athletes was five years higher at hospital admission than any of the other groups. When age was accounted for, endurance athletes were 1.73 times more likely than control subjects to be admitted to the hospital for osteoarthritis. Power sport athletes and mixed sport athletes were 1.90 and 2.17 times more likely than control subjects to be hospitalized. Buckwalter and Lane [35] found an increased risk of articular cartilage degeneration in men and women participating in high impact sports which resulted in the development of osteoarthritis. He observed that moderate habitual exercise does not increase risk of osteoarthritis and certain moderate physical activities improve strength and mobility in older people with mild to moderate osteoarthritis. This research supported previous conclusions [36-39]. Abnormal joint anatomy or alignment, previous joint injury or surgery, joint instability, above-average body weight, disturbances of muscle innervations of a joint, or inadequate muscle strength seemed to increase risk [37]. Recent studies consistently show an increased risk of hip/knee osteoarthritis in chronic exercisers [33,38]. This is more prevalent in anaerobic sports than in endurance sports, though runners who train heavily, or at high-intensities may be exposed to increased risk of hip and knee osteoarthritis, compared with moderately active controls [38]. Former athletes display the radiological signs of osteoarthritis appear as osteophytes and subchondral sclerosis [38]. Both joint injury and joint stress contribute to the development of osteoarthritis. Many researchers have examined how sports participation may play a role in the development of arthritis. Soccer is associated with joint overload and risk of injury to the knee [16,29]. There is an increased incidence of cruciate ligament and meniscus injury among soccer players and more reported cases of arthritis [29,38]. Roos [30] found radiological signs of arthritis present in 50 percent of soccer players after 15 years. They found elite-level soccer to be associated with an increased risk of knee osteoarthritis even if cases of trauma-induced cases were excluded. An increased risk of hip osteoarthritis in former elite soccer players was also found, but below the elite level, soccer was not associated with an increased risk of knee or hip osteoarthritis. Long-distance running below the elite level has not been found to be associated with an increased risk of osteoarthritis [29], but extreme, high-intensity long-distance running may contribute to osteoarthritis of the hip or in the knee [29,39-41]. This is an important distinction, in that it suggests that more moderate activity does not confer greater risk, rather it is extreme training that predisposes to injury. Kettunen et al. [41] evaluated lower-limb explosive strength by measuring vertical jumping height in former male runners, soccer players, weightlifters, and shooters. Athletes with osteoarthritis had significantly lower vertical jumping heights. Age, reported hip and knee disability, and knee pain reduced jumping height. Recent physical activity was associated with improved vertical jumping height.

Hip Injuries

Physical load from sport activities seems to be a risk factor for the development of severe osteoarthritis of the hip. In a study examining the relationship between sporting activities and hip osteoarthritis, women with high sports exposure and those with medium sports exposure had a significantly higher risk of developing the disease compared with those with low exposure [42-45]. The relative risk of developing hip osteoarthritis leading to total hip replacement was 2.3 for those with high sports exposure and 1.5 for those with medium sports exposure.

Schmitt et al. [6] studied the occurrence of hip arthritis in former elite javelin throwers and high jumpers. Hip arthritis was more common in both groups than in the controls. Despite considerable radiographic degenerative changes, the reduction of function in activities of daily living was minimal compared to a control group.

To study factors associated with passive hip rotation range of motion (ROM) in former elite male athletes, Kettunen et al. [41] interviewed athletes about hip pain and disability. There were no differences in passive hip rotation between former elite male long distance runners, soccer players, weight lifters, and shooters. Yet, hip rotation was lower in subjects with a high BMI than in those with low BMI, suggesting obesity may be associated with hip disability. Marti and Knobloch [42] examined former elite athletes (average age = 42 yr) and a control group. The athletes had more radiological signs of degenerative hip disease than non-runners.

Knee Injuries

Knee injury is the most common reason for permanent disability due to sports injury [26,29,46-48]. Anterior cruciate ligament (ACL) injury has been linked to an increased risk of developing osteoarthritis [25,26,29]. A rupture of the ACL is commonly followed by problems such as knee instability, meniscus rupture, cartilage damage, and osteoarthritis of the knee later in life [29]. The incidence of knee osteoarthritis is increased if associated with meniscal injuries or ligament ruptures [24,25,29]. Continuing physical activity may help to maintain function, but knee osteoarthritis is reported to decrease the overall quality of life with age [26,49]. Kettunen et al. [49] determined that compared with endurance athletes and controls, team sport athletes had a higher risk of knee disability. Athletes in sports that involve a high risk of knee injury reported more pain, disability, and osteoarthritis. All athletes had a higher risk, relative to controls, of knee osteoarthritis before age 45, and team sports competitors had the highest risk. Data showed that former elite male endurance athletes and track and field athletes had less hip disability than controls (after adjustment for age, BMI, occupational group), but more reported hip osteoarthritis.

Manninen et al. [47] examined physical exercise and risk of severe knee osteoarthritis requiring arthoplasty. He found that recreational exercisers had a significantly lower incidence of knee replacements than controls. Former athletes had the highest rate of knee replacements. He concluded that athletic competition requires a person to compete often with inadequate recovery and through injury, thus leading to the increased rate of knee replacements. Research [50,51] has indicated that female athletes have a higher risk of knee injury than males in sports where jumping and cutting are involved. Specifically, anterior knee pain and non-contact anterior cruciate ligament (ACL) injuries are more common in females than males who compete on a similar level of competition. Anatomical parameters are thought to be at least one contributing factor.

Jumper's knee or patellar tendonitis is an overuse injury characterized by inflammation in the tendon that connects the patella to the tibia. Long-term prognosis of jumper's knee was studied in a 15 year follow-up study [52]. Athletes with jumper's knee were compared with athletes void of knee problems. At baseline, all subjects underwent clinical examinations and completed a questionnaire. Twenty athletes with jumper's knee and 16 of the controls responded to the follow-up questionnaire. The athletes with jumper's knee reported more knee pain than controls and more knee pain after they performed repeated squatting. In the cases of jumper's knee, 53% of subjects reported they had quit their sport due to pain, compared to only 7% of the control athletes. Kujala et al. [29] examined the impact of different physical loading conditions on knee osteoarthritis. He compared 117 former elite male athletes comprised of 28 long-distance runners, 31 soccer players, 29 weight lifters, and 29 shooters. The prevalence of osteoarthritis based on radiographic examination was 3% in shooters, 29% in soccer players, 31% in weight lifters, and 14% in runners.

The risk for having knee osteoarthritis was increased in subjects with previous knee injuries, high BMI at the age of 20, previous participation in heavy work, kneeling or squatting work, and in subjects participating in soccer. Soccer players and weight lifters appear to be at increased risk of developing premature knee osteoarthritis. The researchers suggested the increased risk is explained by knee injuries in soccer players and by high body mass in weight lifters.

Hannan et al. [50] found that habitual physical activity was not associated with knee osteoarthritis in the recreational exerciser. Prior research by Roos [30] indicated that non-elite sports and moderate exercise done did not pose a risk for later development of hip or knee osteoarthritis, supporting previous work [52,53]. They concluded that little risk was involved in recreational running after a 5-year study looking at the risk of osteoarthritis with running and aging.

Upper-Extremity Injuries

Although the number of lower-limb injuries is higher than upper-limb injuries in many sports, different upper extremity and shoulder injuries can also cause permanent disabilities [26,54-57]. Rotator cuff ruptures are common in throwers and tennis players, and long-term problems can occur [26,58]. Recurrent humeral dislocations and injuries leading to cartilage breakdown in the elbow joint also cause long-term problems [26,54]. Tendon injuries of the hand and wrist region are found to cause permanent disability [59,60].

Superior labrum anterior posterior lesions are common in overhead throwing sports [15]. Yehl et al. [58] investigated the application of high local stress via repetitive loading of the long head of the biceps tendon attached to the superior labrum. He found that the stress magnitudes were highest for the deceleration phase at the labrum glenoid interface for all biceps origins. He concluded that deceleration could be the throwing phase that causes tearing at the superior labrum. Schmitt et al. [59] examined long-term changes in shoulder and elbow joints of former elite javelin throwers. Of 21 elite javelin throwers, five athletes complained about shoulder pain in their throwing arm affected activities of daily living, and 14 athletes had a deficit of internal rotation of at least ten degrees. Complete ruptures and partial tears of the rotator cuff were frequent among all former athletes. Three athletes complained about elbow pain in their throwing arm affecting activities of daily living, and 10 athletes had a deficit of extension of more than five degrees. Dominant elbows of all subjects were found to have osteophytes and sclerosis. Athletes who trained with throwing weights of more than 3 kg had a significantly higher risk of degenerative changes than javelin throwers who did not [61,62].

Ankle Injuries

Long-term problems have been seen with ankle injuries [26,63] such as ankle instability. Kujala et al. [29] demonstrated that 16% of patients studied with ankle inversion trauma reported ankle pain 7 years after the injury, and 4% experienced pain at rest. He also found that lateral ankle sprain may be associated with functional ankle instability and recurrence of sprains [25,26]. Knoblach et al. [61] studied the influence of long-term, high-intensity physical training on premature osteoarthritis of the ankle joint. Former members of the 1973 Swiss National team were examined in a retrospective cohort study in 1988. Long-distance runners, especially the orienteers, showed significantly more radiological signs of degenerative ankle disease than controls. Orienteers reported significantly more functional instability of the ankle than track and field runners. Twenty-two former elite volleyball players were examined by Gross and Marti [62] to estimate the influence of long-term, high-intensity volleyball playing on premature osteoarthritis of the ankle joint. Twenty had suffered from at least one ankle sprain, 10 had had ruptures of the lateral ligaments, eight of which required surgery, and four players had severe mechanical instability. Subchondral sclerosis and osteophytes were more prevalent in volleyball athletes than in controls, while the difference in joint space was not significant.

Schmitt et al. [63] examined degenerative changes in the ankle joints of former elite high jumpers.

There were marked differences between takeoff and swinging leg. Athletes who reported injuries in the past had worse radiological scores, indicating more degenerative changes. Severe arthritis with narrowing of the joint space was rare.

Low-Back and Spinal Injuries

Severe permanent disabilities due to spinal injuries are uncommon in sports [26]. Competing in sports may cause an increased number of anatomical changes in the spine, since it is vulnerable during adolescence [64-67]. It has not been determined what spinal changes are reasons to refrain from athletics during growth. The risk of problems later in life is unclear [26,67]. The effect of physical activity on radiographic changes in the lumbar spine is unclear. Schmitt et al. [65] studied the occurrence of radiographic changes of the lumbar spine in former elite athletes across track and field disciplines. Shot putters, discus throwers, and high jumpers showed a higher prevalence of osteophytes than runners. The highest prevalence of radiographic changes in the lumbar spine was observed in javelin throwers, and this supported prior research [68-71]. There were no differences found in limitations in activities of daily living. Researchers agree that because the lumbar spine is more highly loaded in throwers and jumpers than in runners, athletes in throwing disciplines and high jumpers have a higher risk of developing vertebral osteophytes of the lumbar spine.

Raty et al. [68] investigated the long-term effects of different loading conditions on lumbar mobility in former male elite athletes from soccer, long-distance running, weight-lifting, and shooting and in control subjects. They found that participation in sports that did not emphasize extremes of spinal range of motion did not appear to lead to significant differences in back mobility with aging. They discovered that occupational loading and disc height narrowing negatively influence spinal mobility.

A study of 21 former elite javelin throwers investigated radiological and clinical symptoms in the lumbar spine [72]. Degenerative changes in the lumbar spine were more marked towards the caudal aspect of the spine. Ten athletes also had spondylotis thesis, yet they showed improvement after their retirement. Proper lumbar spine capacity is important for pain prevention in later life, as low-back pain is such a debilitating condition.

Lundin et al. [70] investigated back pain and radiological changes in the thoraco-lumbar spine in 134 former top athletes, representing wrestling, gymnastics, soccer, and tennis, and in 28 non-athlete controls. There were significantly more radiological abnormalities among athletes, but they did not report higher frequency of back pain than controls. A decrease in disc height in one or more of the intervertebral discs was highly correlated with back pain in athletes. Videman et al. [71] examined the long-term effects of physical activity on back pain in former athletes. Odds ratios for back pain were lower in athletes than control subjects. Lumbar magnetic resonance images of the runners, soccer players, weight lifters, and shooters were compared. Disc degeneration and bulging were most common in weight lifters and soccer players. Weight lifting was associated with greater degeneration throughout the entire lumbar spine. Soccer was associated with degeneration in the lower lumbar region. Runners showed no signs of accelerated disc degeneration. Complaints of back pain were less common in athletes than control subjects. Activity level was not assessed in controls.

Muscle and Tendon Injuries

Muscle and tendon injuries such as repeated partial tears and total ruptures can lead to long-term problems [26]. Research showed that a typical partial muscle rupture usually heals well without causing long-term problems [26]. Myositis ossificans, the growth of extra-osseous new bone, is a complication of direct blow injury or muscle rupture which may lead to permanent disability [26]. The tendineal rupture of hamstring muscle origin needs operative care to avoid long-term problems [26]. Many muscle ruptures, such as that of pectoralis major and rectus femoris, will lead to permanent problems after the athletic career if the rupture is not treated [26,73-75]. Permanent problems may be cause for disability during activity in later life Chronic Achilles peritendinitis/tendinosis or once ruptured Achilles tendon can cause problems later in life [26,76,77]. The Achilles tendon is the most commonly injured tendon in running sports [26,78]. Many patients will not heal well after tearing their Achilles. Non-operative and operative treatment results in stiffness, thickness and weakness at times and may follow with everyday symptoms and functional disturbance [76,77]. An Achilles tendon overuse injury may limit physical activities in the future, no matter what treatment is used. Complete Achilles tendon ruptures are found more often in athletes who participate in power sports involving explosive acceleration or maximal effort [26,77,78] than those competing in endurance sports.

Performance declines greatly when an Achilles tendon overuse injury occurs. Research indicated that the treatment of Achilles tendon overuse injuries is often incorrect [76]. Most athletes recover completely, but permanent problems can occur with overuse injuries if they are not treated properly. Moller et al. [75] followed 153 cases of total Achilles tendon rupture diagnosed between 1987 and 1991. Two-thirds of the injuries were caused by sporting activities, most often racquet sports. The only non-sports ruptures were in older subjects. Compared to incidence during 1950-73, there was an increase in both sports and non-sports injuries. Patients followed during 1950-1973 were also older than the 1987-91 group. Moller et al. classified patients with Achilles tendon ruptures into two subgroups: young or middle-aged athletes and older non-athletic persons. The increased frequency in the young athletes was explained by increased participation in recreational sports.

Fractures

Low bone mass leading to stress fractures is a problem in female athletes [24]. Braam LA et al. [76] examined factors affecting bone loss in endurance athletes, and showed that high training volumes at high intensities had a detrimental effect on bone in both men and women. Bone mineral density in the lumbar spine remained constant, but bone density in the femoral neck decreased significantly after two years in female athletes. The decrease was highest in amenorrheic athletes. The rate of bone loss in three groups (amenorrheic, eumenorrheic, estrogen supplemented groups) of female athletes was unexpectedly high; neither estrogen nor vitamin K supplementation prevented bone loss in the follow-up study. High-intensity training with absence of proper nutrition and/or monitoring of menses over several years in women may be a risk factor for osteoporosis [24]. Intra-articular fractures, non-union of stress fractures, as well as malpositions after fractures can lead to disability and joint degeneration [26]. Bone fracture with subsequent immobilization and disuse of the injured extremity leads to a rapid loss in local bone mass [26,79,80]. The decrease in bone mass after a fracture is often irreversible. The severity of loss in bone mass is dependent on the type of treatment, how long the patient is immobilized, and the duration of impaired function of the injured limb [80,81]. A fracture in the lower extremity may lead to a more prominent loss of bone than that found after an injury of the upper extremity [4]. Prior research has shown substantial reductions in bone mass at adjacent sites proximal and distal to fracture sites in extremities [4,80,82]. Multiple stress fractures in elite athletes have recently been documented [83]. There was an average of 3.7 fractures in each athlete measured. The fracture site was the tibia or fibula in 70% of the fractures in men, and the foot and ankle in 50% of the fractures in women. Biomechanical factors associated with multiple stress fractures were high longitudinal arch of the foot, leg-length inequality, and excessive forefoot varus. Nearly half of the female patients reported menstrual irregularities. Runners with high weekly training mileage (117 km average) were found to be at risk of recurrent stress fractures of the lower extremities. Prior research indicated baseball pitchers with high loads may also be susceptible to repeat stress fractures [84-86]. Former female athletes have an even higher incidence of stress fractures and osteoporotic changes due to greater risk factors [83,87]. Pettersson et al. [85] examined bone mass differences between female long-distance runners with amenorrhea and those with eumenorrhea. Bone mineral density was significantly lower in the total body, humerus, spine, lumbar spine, pelvis, femoral neck, trochanter, total femur, femur diaphysis, tibia diaphysis and in the nonweight-bearing head of the femur in the amenorrheic group. They concluded that physical weight-bearing activity may not compensate for reduced estrogen levels even in weight-bearing bones of the lower extremity and spine. This finding supports prior research [88-90].

Keen and Drinkwater [87] examined changes in bone mineral density of former oligomenorrheic or amenorrheic athletes after several years of normal menses or use of oral contraceptives. Vertebral bone mineral density was significantly lower in the group who never menstruated regularly compared with the group who menstruated at both time of recruitment and at follow-up, eight years later. After eight years of normal menses or use of oral contraceptives, the mean vertebral bone mineral density of former oligo-amenorrheic athletes remained low, being 84.4% of the regularly menstruating group's value compared to 84.8% at recruitment. Those experiencing menstrual regularity with intermittent oligo/amenorrhea remained at an intermediate position of 94.7% of the regular menstruating group's values.

Injury Occurrance

Different sports produce a specific set of injuries. Finnish researchers analyzed the types of injuries sustained by different athletes [46]. Soccer and basketball leg injuries were found to be most frequent. Permanent disability resulted most often from knee injuries. This research supports previous findings [91]. Violent body contact during the game significantly increased the risk of wounds and injury. Half of all injuries occurred during competition. The study also concluded that preventive teeth guards and tougher game rules may decrease violent contact and injury risk.

A study to determine the frequency and severity of injury in men's college football at a Canadian University found the annual proportion of injured athletes ranged from 53.5% to 60.4% [92]. Concussion, hamstring strain, and brachial plexus injuries were the most common injuries. Knee injuries resulted in the highest rate of severe injury and resulted in the greatest loss of playing time. Ligament sprains and muscle strains and spasms accounted for half of the injuries. A total of 65% of injuries were related to contact between players or between players and other obstacles.

A study by Dvorak and Junge [90] estimated that the frequency of football injuries was approximately 10 to 35 per 1000 playing hours. The majority of injuries occur in the lower extremities to the knees and ankles. Researchers believed the number of head injuries was probably underestimated [93,94]. In a study of basketball injuries [95], of 142 athletes, 215 injuries occurred (44.7% of players injured) over the 2-year study period. The greatest number of injuries resulting in more than seven sessions of time loss involved the knee. The most common injuries causing fewer than seven sessions of time loss involved the ankle. The most common mechanism of injury was contact with another player, especially in the lane. Injuries occurred 3.7 times more often in games than during practice. Centers had the highest rate of injury, followed by guards and forwards. Powell and Barber-Foss [93] investigated the incidence of injuries for girls participating in high school sports versus boys. The injury rates per 100 players for softball (16.7) and for girls' soccer (26.7) were higher than for baseball (13.2) and boys' soccer (23.4). The knee injury rates per 100 players for girls' basketball (4.5) and soccer (5.2) were higher than for their male counterparts in soccer (4.2). Major injuries occurred more often in girls' basketball (12.4%) and soccer (12.1%) than in boys' basketball (9.9%) and soccer (10.4%). Baseball players (12.5%) had more major injuries than softball players (7.8%). There were more surgeries, particularly knee and anterior cruciate ligament surgeries, for female basketball and soccer players than for boys or girls in other sports. Surgery increases the risk for development of osteoarthritis.

The influence of elite track and field activities on the musculoskeletal system was studied by Vingard et al. [94]. Arthritis of the hip was found in eight percent of the athletes and only two percent of non-athlete controls. The distribution was similar between the groups for other musculoskeletal disorders. The prevalence of arthritis of the knee tended to increase, but neck and shoulder disorders were lower in the athlete group.

The lifetime occurrence of musculoskeletal symptoms in former elite male athletes was studied by Raty et al. [95]. Weight-lifters, soccer players, long-distance runners, and shooters were part of the study. Runners had less monthly back pain during the past year than the other athletes. Monthly back pain was most common in weight-lifters. The average intensity of back pain during the past year was highest in weight-lifters and soccer players. Knee pain at least once a month during the past year was reported by 52% of the soccer players, 31% of the weight lifters, 21% of the runners, and 17% of the shooters. Soccer players had the highest number of sports-related knee injuries, and prior knee injuries were associated with knee pain later in life (31%). A predisposition to knee injuries in soccer players may increase the risk of future knee pain. Long-distance runners may be prone to an increased risk of hip pain. More runners reported having hip pain episodes during their lifetime than other athletes.

Data concerning the number of young athletes who received injuries that led them to relinquish their sports career and that caused disability later in life are missing. The number of severe permanent disabilities due to sports injuries seems to be low, and it is unknown how many injuries cause mild disability and a reduction in the quality of life. The most common injury from sports participation that causes later disability is knee injury leading to osteoarthritis.

NCAA Injury Surveillance Database

The National Collegiate Athletic Association (NCAA) has compiled a database of injuries to college athletes [96]. The data is reported by each respective sport and University. During the 2003-2004 school year, the game injuries reported to the NCAA were calculated for each sport. The NCAA reported game injuries per 1000 exposures, with exposures being defined as the number of athletes per sport multiplied by the total number of games. Football reported 33 game injuries per 1000 exposures, women's soccer followed with 15.5, women's gymnastics reported 14 injuries, while men's and women's basketball both reported 9.0 injuries. Baseball, softball, and volleyball each reported less than 6 injuries per 1000 exposures. An important observation is the fact that football has more than twice as many injuries per 1000 exposures, and football teams have a large roster which includes many athletes who are never in the game.

The injury rate during practices was also reported for 2003-2004. Spring football reported 7.5 injuries per 1000 athlete-exposures, women's soccer reported 5.2, football reported 4.1 injuries in practice when excluding spring football, women's gymnastics reported 3.5, men's and women's basketball reported 3.9 and 4.0, respectively. Softball and baseball both had injury rates under 3.0. When examining absolute numbers, the percentage of all injuries occurring in practices versus those occurring in games can be determined. Gymnastics reported 72.6% of injuries occur in practice, while 27.4% occur during competition. Volleyball reported 67.5% in practice, 32.5% in games, while men's basketball reported 65.8% in practice, and 34.2% in games. Football reported 59.1% of injuries occur during practice and 40.9% occur during the game. Women's soccer reported 49.7% of injuries occur in practice and 40.3% during the game. Baseball reported 44.3% in practice, and 56.7% during the game, while softball reported similar numbers with 47.4% on injuries occurring during practice, and 52.6% occur during the game. These numbers are important in that the number of practices for each sport is far greater than the number of games. When looking at football, consider that approximately 12 games are played each year and there are far more practices, but 40.9% of injuries occur during the games. Softball and baseball report even more dramatic numbers, with significantly more injuries occurring during the games. Data from the NCAA indicates that many of the injuries in those sports occur as a result of being hit by the ball, or by making contact with another player, both of which occur very rarely in practice. When examining each sport on an individual basis, women's soccer reports an absolute number of injuries for games (535) and for practices (557) reported from 99 schools. Men's basketball reported 590 injuries during practices and 307 during games, with 119 schools reporting. Women's basketball had 111 schools report 481 practice injuries and 279 game injuries. Both men's and women's basketball indicated that the majority of injuries were due to contact in the lane, when rebounding or defending. Knee, ankle, foot, and leg injuries were most common. Women's gymnastics had only 10 schools report injuries. Of those 10 schools, 53 injuries were reported during practice and 20 were during competition. The majority of injuries sidelined the gymnasts for more than 10 days. Ankle, knee, lower back, and head injuries were most common. Floor exercise, bars, and beam were where the injuries occurred, and most injuries were reported as overuse injuries or injuries due to landing. Football reported 2771 injuries during practice and 1920 injuries during games, with 110 schools reporting. Rushing plays caused the majority of injuries. Leg, knee, ankle, shoulder, head, neck, and lower back were common injuries. Heat was listed as a major cause of injury. Tackling or being tackled, blocking or being blocked, impact with the field, being stepped on or fallen on, and overuse injuries were all common causes of injury. Running backs and wide receivers were the most commonly injured players. Linemen, linebackers, defensive ends, defensive backs, and safetys also reported injuries often. The majority of the injuries that occurred in games were determined to be the result of a legal hit, with 1889 hits being legal and only 33 determined to be illegal. Spring football injuries were reported by 67 schools. These injuries were not included with the regular season football injuries and are considered a separate category. Rushing plays and plays with contact were the most common causes reported with the 562 reported injuries. Head, shoulder, leg, knee, and ankle were the most common injury sites. Running backs, linemen, receivers, linebackers, defensive backs, and safety's were again the most common positions to report injuries.

Women' softball had 247 practice injuries and 274 game injuries reported by 131 schools. Most injuries occurred during innings 4-6. Shoulder, lower back, leg, knee, ankle, head, elbow, hand, and forearm were all common injury locations. Base runners, batters, pitchers, and catchers reported the majority of injuries. Being hit by a pitch, making contact with the ball, ground, or opposing player, and throwing were all instances where injuries were reported.

It is important to note the apparent difference in the total number of injuries in football versus other sports. The absolute number of injuries in football practice was 2771 and during the games 1920 were reported by 110 schools. This was not including spring football practice, where 562 injuries were reported by 67 schools. The sport with the next highest absolute number of injuries was men's basketball, where 590 practice injuries and 307 game injuries were reported by 119 schools. Football reported almost 6 times more total injuries than the sport with the next highest number. The number of injuries occurring during games is another important point. The practices, in all sports, greatly outnumber the games, and football typically has fewer games than other sports, with 11 games being an average season. Injuries occurring in those 11 games make up 42% of the injuries during the football season [100-104].

Conclusions

The majority of injuries in athletes appear to occur in the lower extremities. Most injuries seem to be knee or ankle injuries. Permanent disability resulted most often from knee injuries. Table 2 summarizes athletic injures and their complications.

Location of Injury	Complication	Findings	Sources
Hip	Osteoarthritis	Common in women with highlmedium sports exposure. Javelin throwers. High jumpers. And runners show degenerative changes.	23, 56, 88, 98
Knee	Osteoarthritis	Common reason for pemianent disability due to sports injury. ACL injury other knee injuries- linked to an increased risk. High BMI- increased risk. Team sport athleteslsports that involve a high risk of knee injury report more pain. Disability. and osteoarthritis. Soccer playersl weight lifters- increased risk. Risk does not increase below elite level or in recreational.	8, 17, 24, 34, 38, 39, 40, 41, 44, 49, 54, 68, 79
	Jumper's Knee	More knee pain after 15 yrs. 53% reported they had quit their sport due to their pain (only 7% of controls).	26
	Replacement	Recreational exercisers have a lower incidence of knee replacements than controls. Former athletes have the highest rate of knee replacements.	54
Upper- extremity	Rotator cuff tears	Pemianent disability in baseball and tennis. Labrum tears in overhead throwing sports. Tears lruptures in javelin throwers (3 kg).	5, 27, 41, 51, 57, 62, 103
	Degenerative changes	Cartilage breakdown in elbow. Osteophytes and sclerosis in javelin throwers.	5, 41
	Tendon Injuries	Hand, wrist	78, 82, 86
Ankle	Osteoarthritis	Long-term. high intensity training is associated with Premature development. Found in long-distance runners and orienteers (more instability and degenerative changes). Elite voleybal Imptures of the lateral ligaments. severe mechanical instability. subchondral sclerosis, osteophytes.	15, 28, 39, 41, 55, 87
	Lateral Sprain	Ankle instability: recurrence of sprains	39, 41
	Inversion Trauma	Long-term pain and disability	39, 41
Low-Back/ Spinal	Osteophytes, Radiological abnormalities	Abnormalities found in gymnastics. tennis. wrestling, and soccer (more than controls). Elite javelin throwers-radiological and clinical symptoms in the lumbar spine. Shot putters, discus throwers, and high jumpers- high prevalence of osteophytes.	32, 41, 50, 85
	Disc	Weight lifting- associated with degeneration	95
	Degeneration, bulging	Throughout lumbar spine. Soocer- degeneration in the lower lumbar region. Bulging common in both.	
Muscle/ Tendon	Rupture or tear	Rupture or tear of pectoralis major and rectus femoris lead to long-term. permanent problems.	41, 64
	Achilles injuries	Most common injury to tendon in running sports. Achilles overuse injury may cause future limitations. Complete ruptures are found more often in athleteswho participate in sports involving explosive acceleration or maximal effort.	41, 60, 65, 77
Fractures	Stress fractures	Female patients reported menstrual irregularities. Runners with high weekly training mileage (117 km average) were found to be at risk of recurrent stress fractures of the lower extremities. Baseball pitchers with high loads may be susceptible to repeat stress fractures.	3, 19, 30, 41, 72, 83, 91, 92
	Low-bone Mass/ Osteoporosis risk	High training volumes at high intensities may have adetrimental effect on bone density (men or women). Highest risk for amenorrhelc athletes: bone loss present regardless. Weight-bearing activity may not compensate for reduced estrogen levels.	41, 46, 63, 69
	Malpositions/ immobility	Disability and joint degeneration. Immobilization and disuse of injured extremity leads to a rapid loss in local bone mass. Fracture in lower extremity- more prominent loss of bone than after an injury of upper extremity. Substantial reductions in bone mass at adjacent sites proximal and distal to fracture sites in extremities.	3, 12, 19, 41, 52

Table 2: Selected Injuries in Elite Level Athletics.

References

1. Fahey T, Insel P, Roth WF, Well (2003) Core Concepts in Physical Fitness and Wellness. New York, 90-102.
2. Kujala UM, Marti P, Kaprio J, Hernelahti M, Tikkanen H, et al. (2003) Occurrence of chronic disease in former top-level athletes. Predominance of benefits, risks or selection effects? Sports Med 33: 553-561.
3. Basilico FC (1999) Cardiovascular disease in athletes. Am J Sports Med 27: 108-121.
4. Järvinen M, Kannus P (1997) Injury of an extremity as a risk factor for the development of osteoporosis. J Bone Joint Surg Am 79: 263-276.
5. Paffenbarger RS Jr, Lee IM (1998) A natural history of athleticism, health and longevity. J Sports Sci 16 Suppl: S31-45.
6. Schmitt H, Brocai DR, Lukoschek M (2004) High prevalence of hip arthrosis in former elite javelin throwers and high jumpers: 41 athletes examined more than 10 years after retirement from competitive sports. Acta Orthop Scand 75: 34-39.
7. Wyshak G (2003) Behavioral practices and mortality in women former college athletes and nonathletes. Health Care Women Int 24: 808-821.
8. Hernelahti M, Kujala UM, Kaprio J, Sarna S (2002) Long-term vigorous training in young adulthood and later physical activity as predictors of hypertension in middle-aged and older men. Int J Sports Med 23: 178-182.
9. Sarna S, Kaprio J, Kujala UM, Koskenvuo M (1997) Health status of former elite athletes. The Finnish experience. Aging (Milano) 9: 35-41.
10. Dey SK, Ghosh C, Debray P, Chatterjee M (2002) Coronary artery disease risk factors & their association with physical activity in older athletes. J Cardiovasc Risk 9: 383-392.
11. Rainey C, Sargent R, Drane J, Valois R, Ward D (1995) Health behaviors and health status comparisons of former college athletes and non-athletes. Applied Research in Coaching and Athletics Annual Boston: American Press 171-190.
12. Bäckmand H, Kaprio J, Kujala U, Sarna S (2003) Influence of physical activity on depression and anxiety of former elite athletes. Int J Sports Med 24: 609-619.
13. Morgan WP, Costill DL (1996) Selected psychological characteristics and health behaviors of aging marathon runners: a longitudinal study. Int J Sports Med 17: 305-312.
14. Pihl E, Jürimäe T, Kaasik T (1998) Coronary heart disease risk factors in middle-aged former top-level athletes. Scand J Med Sci Sports 8: 229-235.
15. Wyshak G (2002) Behavior, Heredity, and Diabetes in College Alumnae. J Womens Health Gend Based Med 11: 549-554.
16. Kujala UM, Sarna S, Kaprio J (2003) Use of medications and dietary supplements in later years among male former top-level athletes. Arch Intern Med 163: 1064-1068.
17. Kujala UM, Kaprio J, Taimela S, Sarna S (1994) Prevalence of diabetes, hypertension, and ischemic heart disease in former elite athletes. Metabolism 43: 1255-1260.
18. Kujala UM, Sarna S, Kaprio J, Koskenvuo M (1996) Hospital care in later life among former world-class Finnish athletes. JAMA 276: 216-220.
19. Pihl E, Jürimäe T (2001) Relationships between body weight change and cardiovascular disease risk factors in male former athletes. Int J Obes Relat Metab Disord 25: 1057-1062.
20. Kujala UM, Sarna S, Kaprio J, Tikkanen HO, Koskenvuo M (2000) Natural selection to sports, later physical activity habits, and coronary heart disease. Br J Sports Med 34: 445-449.
21. Frisch RE, Wyshak G, Albright NL, Albright TE, Schiff I, et al. (1992) Former athletes have a lower lifetime occurrence of breast cancer and cancers of the reproductive system. Adv Exp Med Biol 322: 29-39.
22. Shephard RJ (1993) Exercise in the prevention and treatment of cancer. An update. Sports Med 15: 258-280.
23. Kujala UM, Sarna S, Kaprio J, Koskenvuo M, Karjalainen J (1999) Heart attacks and lower-limb function in master endurance athletes. Med Sci Sports Exerc 31: 1041-1046.
24. Kujala UM, Kaprio J, Sarna S (1994) Osteoarthritis of weight bearing joints of lower limbs in former élite male athletes. BMJ 308: 231-234.
25. Kujala U, Orava S, Parkkari J, Kaprio J, Sarna S (2003) Sports career-related musculoskeletal injuries: long-term health effects on former athletes. Sports Med 33: 869-875.
26. Lequesne MG, Dang N, Lane NE (1997) Sport practice and osteoarthritis of the limbs. Osteoarthritis Cartilage 5: 75-86.
27. Spector TD, Harris PA, Hart DJ, Cicuttini FM, Nandra D, et al. (1996) Risk of osteoarthritis associated with long-term weight-bearing sports: a radiologic survey of the hips and knees in female ex-athletes and population controls. Arthritis Rheum 39: 988-995.
28. Kujala UM, Kettunen J, Paananen H, Aalto T, Battié MC, et al. (1995) Knee osteoarthritis in former runners, soccer players, weight lifters, and shooters. Arthritis Rheum 38: 539-546.
29. Koh J, Dietz J (2005) Osteoarthritis in other joints (hip, elbow, foot, ankle, toes, wrist) after sports injuries. Clin Sports Med 24: 57-70.
30. Roos H (1998) [Increased risk of knee and hip arthrosis among elite athletes. Lower level exercise and sports seem to be “harmless”]. Lakartidningen 95: 4606-4610.
31. Vingård E, Alfredsson L, Malchau H (1997) Osteoarthrosis of the hip in women and its relation to physical load at work and in the home. Ann Rheum Dis 56: 293-298.
32. Vingård E, Alfredsson L, Goldie I, Hogstedt C (1993) Sports and osteoarthrosis of the hip. An epidemiologic study. Am J Sports Med 21: 195-200.
33. Gelber AC, Hochberg MC, Mead LA, Wang NY, Wigley FM, et al. (2000) Joint injury in young adults and risk for subsequent knee and hip osteoarthritis. Ann Intern Med 133: 321-328.
34. Cooper C, Inskip H, Croft P, Campbell L, Smith G, et al. (1998) Individual risk factors for hip osteoarthritis: obesity, hip injury, and physical activity. Am J Epidemiol 147: 516-522.
35. Buckwalter JA, Lane NE (1997) Athletics and osteoarthritis. Am J Sports Med 25: 873-881.
36. Gross P, Marti B (1997) [Sports activity and risk of arthrosis]. Schweiz Med Wochenschr 127: 967-977.
37. Lane NE (1996) Physical activity at leisure and risk of osteoarthritis. Ann Rheum Dis 55: 682-684.
38. Lane NE, Michel B, Bjorkengren A, Oehlert J, Shi H, et al. (1993) The risk of osteoarthritis with running and aging: a 5-year longitudinal study. J Rheumatol 20: 461-468.
39. Kettunen JA, Kujala UM, Räty H, Sarna S (1999) Jumping height in former elite athletes. Eur J Appl Physiol Occup Physiol 79: 197-201.
40. Vingård E, Alfredsson L, Malchau H (1998) Osteoarthrosis of the hip in women and its relationship to physical load from sports activities. Am J Sports Med 26: 78-82.
41. Kettunen JA, Kujala UM, Räty H, Videman T, Sarna S, et al. (2000) Factors associated with hip joint rotation in former elite athletes. Br J Sports Med 34: 44-48.
42. Marti B, Knobloch M (1991) [Subjective health and career status of former top athletes. A controlled 15-year follow-up study]. Schweiz Z Sportmed 39: 125-131.
43. Kujala UM, Taimela S, Antti-Poika I, Orava S, Tuominen R, et al. (1995) Acute injuries in soccer, ice hockey, volleyball, basketball, judo, and karate: analysis of national registry data. BMJ 311: 1465-1468.
44. Lian Ø, Refsnes PE, Engebretsen L, Bahr R (2003) Performance characteristics of volleyball players with patellar tendinopathy. Am J Sports Med 31: 408-413.
45. Panni AS, Tartarone M, Maffulli N (2000) Patellar tendinopathy in athletes. Outcome of nonoperative and operative management. Am J Sports Med 28: 392-397.
46. Kettunen JA, Kujala UM, Kaprio J, Koskenvuo M, Sarna S (2001) Lower-limb function among former elite male athletes. Am J Sports Med 29: 2-8.
47. Manninen P, Riihimaki H, Heliovaara M, Suomalainen O (2001) Physical exercise and risk of severe knee osteoarthritis requiring arthroplasty. Rheumatology (Oxford) 40: 432-437.
48. Dugan SA (2005) Sports-related knee injuries in female athletes: what gives? Am J Phys Med Rehabil 84: 122-130.

49. Kettunen JA, Kvist M, Alanen E, Kujala UM (2002) Long-term prognosis for jumper's knee in male athletes. A prospective follow-up study. Am J Sports Med 30: 689-692.

50. Hannan MT, Felson DT, Anderson JJ, Naimark A (1993) Habitual physical activity is not associated with knee osteoarthritis: the Framingham Study. J Rheumatol 20: 704-709.

51. Cain EL Jr, Dugas JR, Wolf RS, Andrews JR (2003) Elbow injuries in throwing athletes: a current concepts review. Am J Sports Med 31: 621-635.

52. Kim DH, Millett PJ, Warner JJ, Jobe FW (2004) Shoulder injuries in golf. Am J Sports Med 32: 1324-1330.

53. Lyman S, Fleisig GS, Andrews JR, Osinski ED (2002) Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med 30: 463-468.

54. Mazzocca AD, Brown FM Jr, Carreira DS, Hayden J, Romeo AA (2005) Arthroscopic anterior shoulder stabilization of collision and contact athletes. Am J Sports Med 33: 52-60.

55. Murray TA, Cook TD, Werner SL, Schlegel TF, Hawkins RJ (2001) The effects of extended play on professional baseball pitchers. Am J Sports Med 29: 137-142.

56. Rettig AC (2004) Athletic injuries of the wrist and hand: part II: overuse injuries of the wrist and traumatic injuries to the hand. Am J Sports Med 32: 262-273.

57. Schepsis AA, Jones H, Haas AL (2002) Achilles tendon disorders in athletes. Am J Sports Med 30: 287-305.

58. Yeh ML, Lintner D, Luo ZP (2005) Stress distribution in the superior labrum during throwing motion. Am J Sports Med 33: 395-401.

59. Schmitt H, Hansmann HJ, Brocai DR, Loew M (2001) Long term changes of the throwing arm of former elite javelin throwers. Int J Sports Med 22: 275-279.

60. Willems TM, Witvrouw E, Delbaere K, Mahieu N, De Bourdeaudhuij I, et al. (2005) Intrinsic risk factors for inversion ankle sprains in male subjects: a prospective study. Am J Sports Med 33: 415-423.

61. Knobloch M, Marti B, Biedert R, Howald H (1990) [Risk of arthrosis of the upper ankle joint in long distance runners: controlled follow-up of former elite athletes]. Sportverletz Sportschaden 4: 175-179.

62. Gross P, Marti B (1999) Risk of degenerative ankle joint disease in volleyball players: study of former elite athletes. Int J Sports Med 20: 58-63.

63. Schmitt H, Lemke JM, Brocai DR, Parsch D (2003) Degenerative changes in the ankle in former elite high jumpers. Clin J Sport Med 13: 6-10.

64. Kujala UM, Salminen JJ, Taimela S, Oksanen A, Jaakkola L (1992) Subject characteristics and low back pain in young athletes and nonathletes. Med Sci Sports Exerc 24: 627-632.

65. Schmitt H, Dubljanin E, Schneider S, Schiltenwolf M (2004) Radiographic changes in the lumbar spine in former elite athletes. Spine (Phila Pa 1976) 29: 2554-2559.

66. Kellgren J, Lawrence J (1957) Radiological assessment of osteoarthritis. Ann Rhem Dis 16: 494-502.

67. Larsen A (1973) Radiological grading of rheumatoid arthritis. An interobserver study. Scand J Rheumatol 2: 136-138.

68. Räty HP, Battié MC, Videman T, Sarna S (1997) Lumbar mobility in former élite male weight-lifters, soccer players, long-distance runners and shooters. Clin Biomech (Bristol, Avon) 12: 325-330.

69. Schmitt H, Brocai DR, Carstens C (2001) Long-term review of the lumbar spine in javelin throwers. J Bone Joint Surg Br 83: 324-327.

70. Lundin O, Hellström M, Nilsson I, Swärd L (2001) Back pain and radiological changes in the thoraco-lumbar spine of athletes. A long-term follow-up. Scand J Med Sci Sports 11: 103-109.

71. Videman T, Sarna S, Battié MC, Koskinen S, Gill K, et al. (1995) The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability, and spinal pathology among men. Spine (Phila Pa 1976) 20: 699-709.

72. Orava S, Kujala UM (1995) Rupture of the ischial origin of the hamstring muscles. Am J Sports Med 23: 702-705.

73. Paavola M, Orava S, Leppilahti J, Kannus P, Järvinen M (2000) Chronic Achilles tendon overuse injury: complications after surgical treatment. An analysis of 432 consecutive patients. Am J Sports Med 28: 77-82.

74. Rettig AC, Liotta FJ, Klootwyk TE, Porter DA, Mieling P (2005) Potential risk of rerupture in primary achilles tendon repair in athletes younger than 30 years of age. Am J Sports Med 33: 119-123.

75. Möller A, Astron M, Westlin N (1996) Increasing incidence of Achilles tendon rupture. Acta Orthop Scand 67: 479-481.

76. Braam LA, Knapen MH, Geusens P, Brouns F, Vermeer C (2003) Factors affecting bone loss in female endurance athletes: a two-year follow-up study. Am J Sports Med 31: 889-895.

77. Baublitz SD, Shaffer BS (2004) Acute fracture through an intramedullary stabilized chronic tibial stress fracture in a basketball player: a case report and literature review. Am J Sports Med 32: 1968-1972.

78. Finsen V, Haave O (1987) Changes in bone-mass after tibial shaft fracture. Acta Orthop Scand 58: 369-371.

79. Magnusson HI, Westlin NE, Nyqvist F, Gärdsell P, Seeman E, et al. (2001) Abnormally decreased regional bone density in athletes with medial tibial stress syndrome. Am J Sports Med 29: 712-715.

80. Korpelainen R, Orava S, Karpakka J, Siira P, Hulkko A (2001) Risk factors for recurrent stress fractures in athletes. Am J Sports Med 29: 304-310.

81. Polu KR, Schenck RC Jr, Wirth MA, Greeson J, Cone RO 3rd, et al. (1999) Stress fracture of the humerus in a collegiate baseball pitcher. A case report. Am J Sports Med 27: 813-816.

82. Schickendantz MS, Ho CP, Koh J (2002) Stress injury of the proximal ulna in professional baseball players. Am J Sports Med 30: 737-741.

83. Soeda T, Nakagawa Y, Suzuki T, Nakamura T (2002) Recurrent throwing fracture of the humerus in a baseball player : case report and review of the literature. Am J Sports Med 30: 900-902.

84. Snow-Harter C, Shaw J, Matkin C (1996) Physical activity and risk of osteoporosis. Osteoporosis. Academic Press, San Diego, CA 511-552.

85. Pettersson U, Stålnacke B, Ahlénius G, Henriksson-Larsén K, Lorentzon R (1999) Low bone mass density at multiple skeletal sites, including the appendicular skeleton in amenorrheic runners. Calcif Tissue Int 64: 117-125.

86. Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, et al. (1994) Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. JAMA 272: 1909-1914.

87. Keen AD, Drinkwater BL (1997) Irreversible bone loss in former amenorrheic athletes. Osteoporos Int 7: 311-315.

88. Eils E, Streyl M, Linnenbecker S, Thorwesten L, Völker K, et al. (2004) Characteristic plantar pressure distribution patterns during soccer-specific movements. Am J Sports Med 32: 140-145.

89. Meeuwisse WH, Hagel BE, Mohtadi NG, Butterwick DJ, Fick GH (2000) The distribution of injuries in men's Canada West university football. A 5-year analysis. Am J Sports Med 28: 516-523.

90. Dvorak J, Junge A (2000) Football injuries and physical symptoms. A review of the literature. Am J Sports Med 28: S3-9.

91. Mair SD, Isbell WM, Gill TJ, Schlegel TF, Hawkins RJ (2004) Triceps tendon ruptures in professional football players. Am J Sports Med 32: 431-434.

92. Meeuwisse WH, Sellmer R, Hagel BE (2003) Rates and risks of injury during intercollegiate basketball. Am J Sports Med 31: 379-385.

93. Powell JW, Barber-Foss KD (2000) Sex-related injury patterns among selected high school sports. Am J Sports Med 28: 385-391.

94. Vingård E, Sandmark H, Alfredsson L (1995) Musculoskeletal disorders in former athletes. A cohort study in 114 track and field champions. Acta Orthop Scand 66: 289-291.

95. Räty HP, Kujala UM, Videman T, Impivaara O, Crites Battié M, et al. (1997) Lifetime musculoskeletal symptoms and injuries among former elite male athletes. Int J Sports Med 18: 625-632.

96. http://www1.ncaa.org/membership/ed_outreach/health-safety/iss/index.html