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Prevention of Overuse Sports Injuries in the Young Athlete

Mark V. Paterno, PT, PhD, SCS, ATC[1,2,3], **Jeffery A. Taylor-Haas, PT, DPT, OCS, CSCS**[1,2], **Gregory D. Myer, PhD, CSCS, FACSM**[1,3,4,5], and **Timothy E. Hewett, PhD, FACSM**[1,6,7]

[1]Sports Medicine Biodynamics Center and Human Performance Lab, Division of Sports Medicine Cincinnati Children's Hospital Medical Center, Cincinnati, OH

[2]Division of Occupational Therapy and Physical Therapy, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

[3]Department of Pediatrics, University of Cincinnati College of Medicine, Cincinnati, OH

[4]Department of Orthopaedic Surgery, University of Cincinnati College of Medicine, Cincinnati, OH

[5]Athletic Training Division, School of Health and Rehabilitation Sciences, The Ohio State University, Columbus, Ohio

[6]The Sports Health and Performance Institute, The Ohio State University, Columbus, Ohio

[7]Department of Physiology and Cell Biology, Orthopaedic Surgery, Family Medicine and Biomedical Engineering, The Ohio State University, Columbus, Ohio

Synopsis

The purpose of this article is to review current theories regarding prevalence, mechanism and prevention strategies for overuse injuries in a young, athletic population. This information will provide valuable insight into the state of current evidence regarding overuse injuries in young athletes as well as potential future directions in the development of overuse injury prevention interventions.

Keywords

Overuse Injury; Mechanism; Injury Prevention; Sports Specialization

Introduction

Participation in organized sports is on the rise in the United States. An estimated 30 to 45 million children participate in organized sports, annually.[1, 2] Concurrent with this increase in participation is an upward trend in year round participation in athletics in either one or multiple sports. The benefits of athletic participation in children as a means to stay active and physically fit are well documented[3] however; an increased prevalence of athletic injury in young athletes has raised concern regarding the safety of intense athletic participation at a young age.[4] Although many of these injuries may represent traumatic

CORRESPONDENCE, Name: Mark V. Paterno PT, PhD, SCS, ATC, Address: Cincinnati Children's Hospital, 3333 Burnet Avenue; MLC 10001, Cincinnati, OH 45229, Telephone: 513-636-0517, Fax: 513-636-0516, mark.paterno@cchmc.org.

incidents, as many as 1/3 [5] to over 50% [6, 7] of these injuries are estimated to be a result of overuse.

Overuse injuries are inclusive of a broad spectrum of injuries within sports medicine. Classically, they are defined as chronic injuries related to “constant levels of physiologic stress without sufficient recover time.”[5] Globally, they can be perceived as the outcome of the difference between the volume of the stress or force applied to the body and the ability of the body to dissipate this stress or force. Injury may result from repetitive microtrauma imposed on otherwise healthy tissue or the repeated application of lesser magnitudes of force to pathologic tissue. Either scenario can lead to a sequelae of tissue breakdown. Unfortunately, the mechanism by which this stress ultimately leads to overuse injuries is not consistent among young athletes.

In the absence of a well-defined mechanism, the development of targeted intervention strategies are more difficult. Traumatic injuries, such as ligament tears, are typically the result of a single macrotrauma on otherwise healthy tissue, which results in tissue failure. Many injury prevention programs attempt to develop the athlete’s neuromuscular control mechanisms to help dampen these external forces and reduce the likelihood of traumatic tissue failure. [8, 9] In the case of overuse injuries, there is significantly less evidence regarding the most efficacious program to reduce the incidence of these injuries. Therefore, current intervention programs which attempt to address potential underlying mechanisms or target specific risk factors which may contribute to abnormally high stress with repeated activities are still in development. The purpose of this manuscript is to highlight prevailing theories of overuse injury mechanisms as well as review the best available evidence for implementation of prevention strategies designed to target overuse injuries in both endurance and pivoting/cutting sports.

Mechanism of Overuse Injury

Factors which increase the likelihood of overuse injuries can be classified as either intrinsic or extrinsic risk factors. Intrinsic factors are categorized as implicit or unique to the individual which may increase the likelihood of sustaining an injury.[3] Factors such as maturational status, body mass index (BMI), gender, anatomic variations and biomechanical movement patterns are all examples of intrinsic risk factors.[10] Theoretically, these factors can affect the ability of the athlete’s tissue to dampen or respond to stress. For example, if an athlete possess a varus knee alignment, they are more likely to experience an increase load on the medial compartment of the knee. Over time, this may lead to more articular cartilage breakdown in the medial compartment. Anatomic variants, such as knee alignment, in the absence of a surgical intervention to re-align the knee, are unmodifiable risk factors. Conversely, intrinsic risk factors such as BMI, strength deficits or altered movement patterns would generally be considered modifiable risk factors, which have the potential to improve with an injury prevention intervention.

Extrinsic risk factors are those factors when applied to the athlete, may increase risk of injury. These may include training methods, equipment and environment[3] and may have an effect on the magnitude or stress or force applied to the body. Training regimes are often implicated as a potential mechanism of overuse injury. Hogan et al [5] identified three scenarios which may increase an individual’s likelihood of developing an overuse injury. The first involves the athlete who attempts to rapidly increase his training load after a period of inactivity or decreased activity. In this situation, the body has an insufficient adaptation period to respond to a higher level of stress and therefore, is not adequately prepared to dissipate repetitive forces. Investigations of the high incidence of stress fractures during the initial stages of training in the military [5, 11] support this theory of overuse injury due to rapid increases in activity.

A second category of extrinsic risk factors includes athletes who attempt to participate at a level which exceeds their individual skill level.[5] In theory, this mismatch of individual skill or fitness level to imposed stress and physical demands can lead to tissue breakdown. Finally, consistent participation at an exceptionally high level is theorized to lead to overuse injury. This group may suffer from excessive microtrauma over time with insufficient rest, ultimately leading to tissue breakdown. Athletes who continuously participate in sports without rest[12] or who specialize in one sport throughout the year[4] are anecdotally thought to be included in this high risk category, however current evidence is sparse.[12]

In summary, overuse injuries are generally a product of the application of an applied load to the body and the body's ultimate inability to dampen the applied load. This may be due to intrinsic factors which limit the body's ability to dampen the load or extrinsic factors which increase the load which is applied. Using this theory, programs designed to prevent overuse injuries should target impairments which decrease the individual's ability to dampen forces applied to the body and encourage participation in appropriate progressions of training to increase the individual's ability to dampen the applied load.

Preventing Overuse Injuries in Young Endurance Athletes

Running is an endurance sport which continues to grow in popularity amongst middle school and high school athletes as over 450,000 young athletes participated in cross-country during 2010–2011[13]. Concomitant with an increase in running participation comes an associated increase in injuries. The annual incidence rate among high school cross-country runners is reported to be as high as 17.0/1000 athletic exposures (AE's) [14]. Unfortunately, the literature on running-related injury prevention is sparse and often contradictory. In addition, the potential confounding effects of growth and maturation on running biomechanics and injury risk in children may also limit the generalizability of adult literature to the pediatric running population. While these challenges exist, focusing on known factors that contribute to pediatric running-related injuries, recognizing the hallmark signs and symptoms of these injuries, as well as having a strong understanding of the underlying biomechanics of distance running may serve to guide clinicians interested in prevention of these injuries in a young population.

Common Pediatric Running-Related Injuries

The most common location of pediatric running-related injuries are shin injuries for girls and knee injuries for boys [14]. The two most common shin injuries are medial tibial stress syndrome and tibial stress fractures. In adolescent runners, the most common knee injuries are patellofemoral syndrome, iliotibial band syndrome, and injuries to the apophysis, such as Osgood-Schlatter Disease (OSD).

Medial tibial stress syndrome (MTSS) is characterized as "an exercise-induced, localized pain along the distal two thirds of the posterior-medial tibia" and affects more long-distance female than male runners [15]. Risk factors for sustained MTSS include reduced running experience [16], a previous history of MTSS [16], and a higher body mass index [15]. While runners with a history of MTSS are more likely to report orthoses use than those runners without a history of MTSS [15], the evidence supporting an association between a pronatory foot type and MTSS is mixed. [15, 17, 18] Adult athletes diagnosed with MTSS have significantly reduced plantar flexor muscle endurance compared to uninjured athletes [19]. While retrospective in nature, this adds support to the theory that a lack of endurance of the plantar flexor muscle group may lead to a higher force transfer to the tibia [20].

Stress fractures occur along a continuum of repetitive loading, bone remodeling, and microdamage accumulation [21] and can be classified as either fatigue or insufficiency fractures. A fatigue stress fracture occurs in healthy bone as the result of repetitive loading and mechanical stress [22], while an insufficiency fracture is the result of normal loading on pathologic bone. [22]. The majority of stress fractures that occur in pediatric long-distance runners can be classified as fatigue stress fractures, with tibial stress fractures as the most common type of stress fracture [23].

Of all running injuries, patellofemoral syndrome (PFPS) is the most common [24, 25] and the etiology is still unclear [26]. Also known as “runner’s knee,” or anterior knee pain PFPS is typically described as pain to the peripatellar region that increases with activities such as running, stair ambulation, squatting, jumping, and/or prolonged sitting with the knees flexed [27]. While many etiological theories exist, two biomechanical pathways have received the most attention. First, a lack of proximal stability due to impaired hip strength and/or hip muscular activation leads to excessive patellofemoral joint stress by increasing the dynamic quadriceps angle acting upon the patellofemoral joint [28] . Second, excessive and/or mistimed pronation may lead to alterations in frontal and transverse plane mechanics at the patellofemoral joint resulting in patellofemoral compression, overuse, and pain [28].

Proximally, the gluteus medius and gluteus maximus function to eccentrically stabilize the femur in the frontal and transverse planes, respectively, while running [29]. Recent systematic reviews suggest adolescent and young adult females with PFPS demonstrate deficits in hip strength [30] and adult runners with PFPS exhibit delayed and shorter muscle activation of the gluteus medius [31]. Together, these studies indicate an association between lack of proximal pelvic girdle stability and PFPS. Furthermore, interventions targeted at improving the strength and neuromuscular control of the hip abductor, hip extensor, and hip external rotator musculature may be efficacious as part of an injury prevention program. Distally, as the foot and ankle complex pronates the tibia internally rotates due to the anatomical wedging of the talus in the distal tibia-fibular mortise [32]. Some authors theorize that excessive or mistimed pronation would lead to excessive patellofemoral stress due to disruptions in transverse and frontal plane timing of transverse plane tibiofemoral joint [33]. However, there is mixed evidence in regards to the association between excessive foot pronation and PFPS [34, 35] [36, 37].

Iliotibial Band Syndrome (ITBS) is the most common cause of lateral knee pain in runners [24], with an annual incidence rate up to 12% [38]. While originally thought of as a sagittal plane disorder secondary to a tight ITB fractioning over the lateral femoral epicondyle [38, 39], more recent evidence supports the theory that ITBS occurs as a result of a lack of frontal and transverse plane control of the femur and tibia [40–43]. Anti-inflammatory treatment is thought to be effective in the acute treatment of subjects with ITBS [38, 44] while hip abductor strengthening has been shown to be effective at improving hip strength and returning injured runners back to function [39, 45].

Osgood-Schlatter Disease (OSD) is the most common apophyseal disorder affecting adolescents [46] and presents as anterior knee pain, swelling, and tenderness to palpation over the tibial tubercle [47]. OSD typically occurs during a growth spurt and is seen most often in adolescents participation in sports involving repetitive running and/or jumping [47, 48]. Tightness to the rectus femoris is associated with OSD [48]. Interventions typically include relative rest, gentle quadriceps stretching, and quadriceps strengthening [47–49]. Because OSD is associated with recent growth, these athletes may benefit in reduction of total running volume as part of an injury-prevention effort.

Risk Factors for Sustaining a Pediatric Running-Related Injury

Intrinsic Risk Factors—Intrinsic risk factors most often associated with running related injuries in a pediatric population include sex, anatomic morphology, running mechanics, hip strength and nutrition. Epidemiological evidence of sex differences is sparse. Rauh and colleagues prospectively tracked high school cross country runners and noted that female runners had a higher injury rate as compared to boys (19.6/1000 AEs vs. 15.0/1000AEs) and sustained more injuries causing >15 days lost from running than boys [14]. Compared with boys, the total injury rate for girls was significantly higher than boys for all injuries except those resulting in 5–14 days lost [14]. Retrospectively, Tenforde and colleagues assessed a large cohort of long-distance runners and noted that females had a higher overall injury rate than males. The authors noted the following, most common injuries: tibial stress injuries, ankle sprain, patellofemoral pain, iliotibial band syndrome, and plantar fasciitis [50].

Risk factors related to anatomic morphology in runners include Q-angle at the knee and foot morphology. Rauh and colleagues report that high school cross country athletes with a standing quadriceps angle (Q-angle) >20 degrees were 1.7 times more likely to sustain a running related injury compared to a standing Q-angle of 10 degrees to <15 degrees [3]. Runners with >4 degrees absolute right-left Q-angle difference were at 1.8 times greater risk compared to runners with a smaller difference. Runners with a Q-angle >20 degrees were more likely to injure their knee, while runners with >4 degrees Q-angle difference were more likely to injure their shin [51].

Anatomical variations related to foot morphology are often theorized to contribute to pediatric running related injuries. Many postulate that a pes planus foot type results is a more mobile foot leading to an increase in pronation excursion and excessive strain to medial soft tissue structures whereas a pes cavus foot type results in a stiffer foot that is less well equipped to dampen GRF at the foot and ankle resulting in excessive bone stresses and lateral column injuries [52]. While multiple authors cite structural deviations of the arch as either indirectly or directly contributing to running injury incidence in both adult civilian and military runners [53–56], others have found no association [57–59]. Further, few studies have prospectively assessed the effect of foot structure on the incidence of PRRI with contradictory conclusions [15, 17, 60, 61]. This has lead one author to state that efforts to optimally “aligning the skeleton” with shoes and orthoses designed to mitigate anatomical variants should be reconsidered [62]. Thus, further high-quality prospective studies are warranted to help delineate the effect of arch structure on the risk of sustaining a running related injury.

Altered running mechanics are theorized to lead to injury. Recently, primary biomechanical faults cited for increased risk of sustaining a running-related injury are excessive rearfoot eversion [56, 63–66] , and altered stance phase impact forces [56, 67–72]. While limited work has been undertaken in the pediatric running athlete, some prospective evidence exists correlating dynamic pronation excursion with the occurrence of exercise-related lower limb pain in a heterogenous cohort of college aged, physical education students [73].

Two studies have demonstrated altered running mechanics in adult females who have sustained tibial stress fractures [56, 66]. In separate cross-sectional, retrospective studies comparing three-dimensional mechanics of female runners with a history of tibial stress fracture to an uninjured cohort, it was noted that the tibial stress fracture groups demonstrated increased peak rearfoot eversion, a component of pronation, compared to controls.[56, 66] Further, Milner and colleagues reported that the tibial stress fracture group also demonstrated significantly higher peak hip adduction while Pohl and colleagues. noted the variables of peak rearfoot eversion, peak hip adduction, and free moment (a measure of impact force) correctly classified 83% (50/60) runners into tibial stress fracture or control group [56]. Taken together, this suggests efforts aimed at reducing pronation and/or hip adduction may reduce the likelihood of developing a tibial stress fracture; however, caution must be noted as cause and effect relationship cannot be ascertained from retrospective studies.

More recently, emphasis has shifted towards assessing hip strength, hip muscular activation, and running gait mechanics to assess the relative impact these variables may have on the development of a running-related injury. A lack of hip strength has been associated with multiple injuries, including patellofemoral pain syndrome (PFPS) [27, 29, 30, 74–79], iliotibial band syndrome (ITBS) [39], and tibial stress fracture [80]. A lack of strength to the hip abductor, hip extensor, and hip external rotator musculature is theorized to place the femur into excessive amounts of adduction and internal rotation leading to alterations in joint coupling and mechanics to the knee, shank, and foot-ankle complex distally [28]. Indeed, there is limited evidence to suggest altered hip strength affects running mechanics in a healthy population [81, 82] and in a population of adult female runners with PFPS [83] . However, while improving hip strength has led to reductions in pain and improvement in function, particularly in subjects with PFPS and ITBS [27, 39, 84] , they have not directly led to changes in running gait mechanics [85, 86]. This seeming contradiction has, in part, caused some investigators to assess the effect of alterations in hip muscular activation and running gait mechanics on the relative risk of sustaining a running-related injury.

Proper nutrition is important for maintaining health and reducing the risk of sustaining a pediatric running related injury. High School cross-country runners with a higher body mass index have a higher risk of sustaining medial tibial stress syndrome than those runners with a lower BMI [15]. Conversely, in a cohort of female collegiate track and field athletes, reduced nutritional fat intake was associated with an increased risk of sustaining a stress fracture [87]. This speaks to the intrinsic risk factors unique to female athletes, such as delayed age of menarche and irregular menstruation. Both menstrual irregularity, such as oligomenorrhea and amenorrhea, as well as a delayed age of attaining the first menstrual cycle are associated with increased risk of sustaining a bony stress-related injury [87–90]. Further female long-distance runners whom demonstrate signs or symptoms of disordered eating are at increased risk of reduced bone mineral density than those runners with more typical eating habits [88].

Extrinsic Risk Factors

Extrinsically, improper training is identified as a contributor to pediatric running related injuries. Progressive training regimes with a focus on a gradual increase in running to help acclimate the body to the rigors of running and thereby reducing the likelihood of sustaining a running-related injury are common . Unfortunately, little evidence exists to support this widely-held belief. A randomized controlled trial did not find a protective effect for a preconditioning program at reducing running related injury rates (RRIR) in novice, adult runners [91]. This is in agreement with Buist et al who found no difference on the RRIR of adult, novice runners utilizing a 13-week graded training program that followed “the 10% rule” for mileage increase when compared to an 8-week control group [92]. Because many pediatric runners can be considered novice runners, or runners whom have been running for less than or equal to two years, these results may provide some insight into the effect of training on the PRRI rate.

The type and duration of previous sports participation may alter the risk of sustaining a running related injury. In novice, adult males training for a 4-mile race, those runners whom had participated in sports without axial loading prior to training, such as swimming and cycling, were more than twice as likely to sustain a RRI than those males whom had participated in sports such as basketball or soccer [93]. This is in agreement with Fredericson and colleagues, whom noted that youth participation in basketball or soccer was protective against the future risk of sustaining a stress fracture in collegiate track athletes

[94]. Taken together, these studies impart two valuable clinical pearls. First, participation in sports that induce axial loading in a three-dimensional fashion may enhance bone mass and thereby reduce the likelihood of sustaining a stress-related RRI. Second, participation in sports where athletes are required to perform sprinting, cutting, and jumping maneuvers may enhance an athlete's neuromuscular control capabilities which might impart a reduced likelihood of sustaining a RRI.

Potential Interventions to Target Altered Mechanics & Reduce Injury Risk

While attempts to reduce the incidence of running-related injuries in adults through graded training programs [91, 92] or by matching shoe-wear to foot-type [95] have proven ineffective, a careful review of the literature on risk factors for sustaining a PRRI as well as treatments for the most common PRRI suggests a pathway towards prevention. The key variables to this pathway may include:

1. Identifying at-risk populations
2. The application of pre-season and in-season hip strengthening program
3. Assessment of running biomechanics.

Based on the epidemiological reports of Rauh et al. [14, 96]l and Tenforde et al. [50] as well as the application of the reports on risk factors for novice runners[91–93, 97, 98], the following characteristics of pediatric and adolescent long-distance runners should be taken into consideration and can be broken down between intrinsic and extrinsic measures. Assessments of four intrinsic measures are recommended. First, measuring the standing quadriceps (Qangle) is recommended based on the aforementioned studies by Rauh and colleagues [14, 51, 99]. Specifically, runners with a Q-angle of >20 degrees and/or runners with a right-left difference of >4 degrees should be noted and the application of modified training programs and/or targeted hip and quadriceps strengthening programs is recommended [14, 51]. Second, measuring the body mass index (BMI) should be considered as increased BMI is associated with medial tibial stress syndrome [15] while reduced BMI may serve as a warning to coaches, parents, and health care professionals that the runner may be at risk for bony stress-related injuries such as stress reaction and stress fractures [100]. Third, the navicular drop test should be considered but caution should be noted in interpreting the results due to the conflicting reports noting its association with MTSS [15, 17, 18], Exertion-Related Lower Limb Pain [101], a condition that encompasses pain between the knee and ankle which occurs with exercise [102], and stress fractures [24]. Fourth, pre-season measures of hip abductor, hip extensor, and hip external rotator strength should be considered due to the fair to strong evidence noting the relationship between hip muscle weakness and conditions such as PFPS [30] and ITBS [39]. Additionally, indirect evidence suggests a possible biomechanical link between hip muscle weakness and TSF [56, 66, 80, 81], however, further prospective studies are warranted. Finally, with regards to female athletes, it is strongly recommended to regularly measure menstrual cycle status and regularity in order to reduce the likelihood of incurring bony stress-related injuries [87–89, 100].

Dynamics evaluation of altered gait mechanics, with the potential for targeted gait retraining, is viewed as a potential new avenue in the evaluation, treatment, and perhaps prevention of pediatric running-related injuries. With regards to stress fractures, multiple authors have noted that adult female runners whom have sustained a tibial stress fracture (TSF) demonstrate altered running kinetics, specifically, increases in loading rate [69, 70] and ground reaction forces [68, 71]. This had led some authors to attempt to retrain running gait mechanics of at-risk and/or injured runners in order to reduce these variables of impact shock that may be associated with injury. Techniques such as real-time visual feedback, [72,

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103] mirror gait retraining [104, 105] and increasing step rate [106] have been used to target altered running mechanics. Taken together, both visual and auditory gait retraining provide clinicians with emerging interventions to address the high incidence of pediatric running related injuries. However, future, prospective research in a pediatric population is warranted in order to determine the effect of gait retraining on the reduction of injuries in at-risk populations.

With regards to modifiable extrinsic factors, three steps are recommended. First, cataloging an athlete's preseason activity-level, by using such valid and reliable tools as the Tegner Activity Scale [99, 100] may be warranted to both determine the athlete's readiness to run as well as their relative risk for sustaining a running related injury. Based on weak to fair evidence in the adult population, determining fitness level prior to running [96, 107] , the length of time running [108] , the type and severity of prior running-related injuries [93] , as well as the types of previous sporting activities [93] are recommended. Second, modifying training volumes and intensity for runners whom have recently undergone a growth spurt are recommended in order to reduce stressors to the apophysis [47, 48]. Finally, early and continued participation in ball sports and/or sports involving a 360-degree playing field are recommended based on weak-to-fair evidence [94]. Providing runners individualized training programs that take into account their fitness level, growth and maturation, prior running-related injuries and affords the runner an opportunity to perform cross-training activities that challenges their coordination and neuromuscular control are recommended to help modify the extrinsic risk factors associated with pediatric running related injuries.

In conclusion, more high-quality, prospective research is warranted to better illuminate the intrinsic and extrinsic risk factors associated with sustaining a running related injury. Further, high-quality randomized controlled trials assessing the effects of pre-season interventions on the incidence and severity of these injuries are necessary to help guide coaches, parents, student-athletes, and health care professionals in making quality decisions regarding evidence-based steps to reduce the likelihood of sustaining a running related injury. While these challenges remain, the continued participation in endurance sports such as long-distance running by pediatric and adolescent youth is recommended as a means of promoting a healthy and well-rounded lifestyle.

Preventing overuse injuries in pivoting and cutting sports

Team sports such as basketball, handball, soccer and volleyball demonstrate increased acute and overuse injury risk relative to individual sports.[109] Injuries to the Anterior Cruciate Ligament (ACL) result in the greatest time lost from sport and recreational participation by young athletes who compete in running and cutting team sports. However, chronic conditions such as patellofemoral pain are the most common disorder of the knee, with its greatest incidence in young, physically active females.[110–114] Interestingly, there is a similar sex disparity in both conditions, as adolescent females and young women who participate in pivoting and cutting sports are affected with PFPS and ACL injury 2–10 times more often than their male counterparts.

Altered mechanics that may predispose to overuse injury

Altered or reduced motor control during physical activities may result in frontal plane dysfunction during running and cutting sports. This frontal plane dysfunction appears to be similar to those described in endurance sports, which may underlie injury risk. For example, in long distance runners, the predictive factor that lead to chronic knee pain was increased knee frontal plane impulse moment during single support stance phase of running.[115] Similarly, as previously noted, Rauh and colleagues reported that high school cross-country runners with abnormal frontal plane static alignments (Q-angle measures of 20 or more degrees) were more likely to miss practice or competition from an injury to their knee.[51] Increased frontal plane anatomical alignments and dynamic knee loads are associated with patellofemoral pain and knee injury incidence has been noted previously with strong evidence in endurance runners, though this association has not been reported previously in other populations. However, recent evidence indicates that similar neuromuscular dysfunction such as frontal plane alignment and control of the knee also appear to increase risk of both acute injury and chronic injury in young females who play competitive team sports.[116, 117]

Current evidence of NM interventions which reduce incidence of overuse injury

It is acknowledged that the volume, intensity and number of competitions vary among both team and individual sports. In addition, overscheduling and other factors such as nutrition and lack of sleep can contribute to overuse injury risk in youth.[118] A recent report indicates that early sport specialization during youth may be associated with increased risk of patellofemoral pain compared to multi-sport athletes.[119] These data further indicate that the variety in sport and exercise may limit the risk of overuse injuries in this population. In addition, participation in a variety of sports may help prevent the development of neuromuscular deficits that likely underlie chronic injury in sport.[120] While extrinsic factors likely contribute to chronic injury risk in running and cutting sports, the current evidence indicates that neuromuscular deficits such as ligament dominance and quadriceps dominance are the primary determinant of both acute and chronic injury risk. If neuromuscular dysfunction underlies both chronic and acute injury risk, this may provide a mechanism to target risk factors that increase injury risk across all sport types and possibly prevent them in the future.[109]

Neuromuscular training focused on frontal plane dysfunction has been effective to reduce deficits which may increase risk of injury.[121–124] In addition neuromuscular training that is focused on increasing hip abduction strength and recruitment may improve the ability of young growing athletes to better control for the increased height of their center of mass and improve dynamic lower extremity alignments to reduce loads which may contribute to the chronic injuries.[125, 126] Accordingly, a similar preseason neuromuscular training protocol was administered to young female athletes and found a reduced prevalence of chronic knee pain at post-season follow-up.[127] Young athletes who have missed a critical window to prevent the development of movement deficits which increase injury risk may be more responsive to specially designed neuromuscular training.[124] Current projects aimed toward the utilization of outlined neuromuscular screening techniques to identify potential “high-risk” young athletes and to target identified factors that put them at “high-risk” with the most appropriate neuromuscular training for their specific observed deficits are well underway.[124, 128, 129] Recent evidence indicates that young athletes categorized as high-risk based on previous coupled biomechanical and epidemiologic studies are more responsive to neuromuscular training[116]. Through identification of young athletes at greater risk for chronic injury, prevention strategies may be substantially improved, however as recently suggested, variety and initiation of training during the younger years before playing competitive years with residual neuromuscular deficits may be the best approach to prevent chronic injury youth.[130–133]

Strengths and Limitations of this work and future directions

There are multiple strengths and limitations to the previously published work in the areas of overuse injuries in young athletes during pivoting and cutting sports, [110–114] ; the biomechanics that may predispose children to these injuries’ [115] and the current evidence regarding interventions that may reduce incidence of these overuse injuries. [130–133] One major limitation with this body of work is that the majority of this work is retrospective in nature. This is a major limitation due to a questionable cause and effect scenario: did the identified factors underlie the onset of the overuse injury, or were they the result of it? However, the more recent studies reported in the literature have been prospective in nature. [115] In addition, many of the prior reported studies are underpowered to draw valid conclusions from their work. Large, multi-center trials are needed to recruit and retain the large numbers of young athletes in longitudinal, prospective cohort studies in order to fully power these Level I and Level II experimental designs. There are multiple qualified multi-disciplanary groups currently developing such powerful predictive studies.

Conclusion

The prevalence of overuse injuries in a young, athletic population is increasing, and the evidence related to risk factors in both endurance and cutting sports in lacking. However the evidence which exists support the potential for specific targeted prevention programs to reduce injury risk. Assessment of risk factors underlying mechanisms of overuse injuries indicate a potential link between acute injury prevention and overuse injury prevention. In addition, preliminary attempts to use targeted neuromuscular training to reduce the incidence of overuse injury shows promise in small cohorts. Future research is warranted to investigate the potential for targeted neuromuscular training to reduce overuse injury rates or if other underlying risk factors need to be addressed before more significant reductions in overuse injury incidence rates are seen.

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