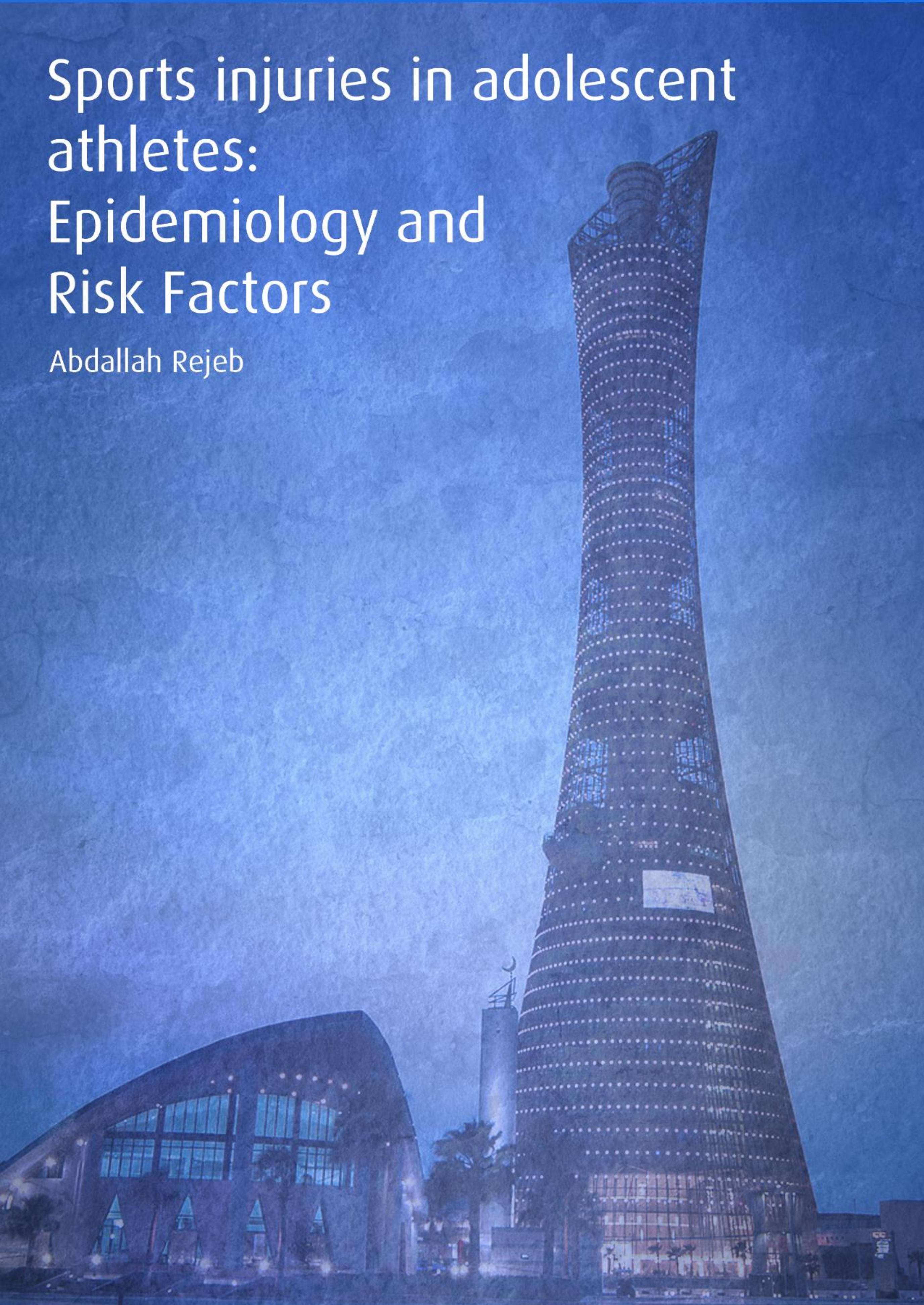
Sports injuries in adolescent athletes: Epidemiology and Risk Factors

Abdallah Rejeb



Sports injuries in adolescent athletes: Epidemiology and Risk factors

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"If you hear a voice within you say, 'you cannot paint,' then by all means paint, and that voice will be silenced."

Vincent van Gogh

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List of abbreviations

%	Percentage
AASMC	Aspire Academy Sports Medicine Centre
ACWR	Acute-chronic Workload Ratio
AIIS	Anterior inferior iliac spine
APHV	Peak height velocity age
ASIS	Anterior superior iliac spine
aka	Also known as
BMI	Body mass index
BS	Beighton score
CA	Chronological age
CI	Confidence interval
DOI	Digital Object Identifier
e.g.	exempli gratia
EM	Early mature
FOPE	Focal periphyseal edema
GJL	Generalized Joint Laxity
G & P	Greulich- Pyle
H	Hour
HR	Hazard ratio
HR	Heart rate
HRmax	Maximal heart rate
i.e.	it est
IOC	International Olympic committee

LM	Late mature
Min	Minute
N	Number- sample size
NM	Normal mature
NTL	Non time loss
LTAD	Long-term athlete development
RR	Relative risk
OCD	Osteochondritis dissecans
OSD	Osgood-Schlatter disease
PHV	Peak height velocity
PMH	Predicted mature height
SA	Skeletal age
SCFE	Slipped capital femoral epiphysis
SD	Standard deviation
SES	socioeconomic status
SLD	Sinding Larsen disease
SPSS	Statistical Package for the Social Sciences
STATA	Statistics and Data Software
ATT	Anterior Tibial Tuberosity
TL	Time loss
TW	Tanner-Whitehouse
WHO	World health organization
Yrs	Years
$\chi 2$	Chi-square

Chapter One

GENERAL INTRODUCTION

INTRODUCTION

There is a widely held and influential belief that physical activity begins to decline at adolescence.[1] The interest in the health, fitness, and well-being of modern-day youth seems to be at an all-time high, with increasing concerns over the prevalence of physical inactivity.[2]

The health, fitness and other advantages of youth sports participation are well recognized.[3] However, the rewards are not without risks, and sport related morbidity is a well-documented problem.[4] Increasing numbers of youth are becoming involved in competitive sport.[3] As sports activities have gained popularity in adolescents and children, this has led to more sports-related injuries.[5] Organized youth sport has become increasingly professionalized, and the associated sports injury problem has received much attention lately.[6]

More sports related injuries logically follow the ever-increasing sports participation in organized and recreational sporting activities at all ages.[5,7]

The kind of sports activity and the mechanism of trauma determine the nature of the lesion.[8] Intensive training at a young age may cause long term harmful effects.[8] Increasingly competitive youth sports around the world require adolescents to undertake more prolonged and intensive training programmes[9] and increased numbers of playing hours. Increased playing is mirrored by an increased risk of traumatic or overuse injury by young sports participants.[10]

OPERATIONAL TERMS

Prior to elaborating on youth, sports and injury, it is pertinent to define key terminologies referred throughout the dissertation.

→ The terms youth and young athletes represent global terms which include both children (generally up to 13 years) and adolescents (typically including boys aged 14– 18 years).[11]

→ Elite athletes, defined as athletes competing at a high national level for their age group.

→ The term " highly trained" was coined to our study cohort as in respect to academy environment (Aspire), on average, every student athlete, irrespective of the sport they have been selected for, were given 8 training sessions/week with a duration of 120 min/session; total of 16 h per week under coach supervision .

→ In the context of Aspire Academy, "multisport" athletes defined as a squad being coached in more than one sport discipline concurrently.

→ The term adolescence is defined by the WHO as the second decade of life, and represents a key period of physical, psychosocial and cognitive development, yet also a period of physical and psychological vulnerability.[12]

INJURY PREVALENCE IN YOUTH SPORTS

In elite youth athletics, approximately six out of ten athletes can expect to encounter an injury resulting in restricted participation or training modifications every season.[13] The overall injury incidence in youth sport is usually in a range of 1 to 10 injuries/1000 hours[6], though based on athlete exposure this rate can increase in sports such as cross country running (10.9–15 injuries/1000 exposures).[14] In a recent study[15] the reported injury incidence in elite adolescent athletes varies from 1.7 to 18.0 per 1000 hours of training and up to 22.4 per 1000 hours of competition. According to[16], the incidence of injury in sports ranges from 0.5 to 34 injuries/1000 hours with injury being one of the leading causes of early retirement from sport.[17] In youth football[18] the number of injuries per 1000 hours of exposure is much higher in the context of competition (11- 24 injuries/1000 hours) than in training (4-7 injuries/1000 hours), giving rise to a relative risk of 2.9.

A prevalent injury rate among adults compared to youth athletes was reported by a study on Swedish adult and youth elite Track and Field population. In fact, Jacobsson and coworkers[19] found that the highest 1-year prevalence was found in male adult athletes (50%), followed by female adult athletes (47%), female youth athletes (44%), and male youth athletes (29%). However, when comparing professional players to youth academies athletes, Price et al[20] found similar injury incidence (48% vs. 52%).

Malisoux et al.[21] reported that high-level athletes engaged in racket or individual sports had a 63% and 66% lower risk of getting injured, respectively compared to team sports. Athletes' characteristics such age, sex, previous injury, training intensity and volume had no significant impact on injury risk. These findings highlighted a hypothesis which stipulated that sport category impact on injury risk would be different in team, racket and individual sports.

Of all injuries recorded, a prevalent rate of traumatic non-contact injuries (42.0%) compared to traumatic contact injuries (34.8%) reported.[21]

Overuse injuries, caused by microtrauma following chronic overload, tend to be frequent in young athletes during their growth spurt, totalizing 30-40% of all injuries recorded.[21] A prospective follow-up demonstrated that young athletes from team sports had a ~2 times higher risk of sustaining a traumatic or overuse injury compared to individual sports.[6] Compared to their adult counterpart, youth soccer players are thought to be at a higher risk of overuse injuries because of the immaturity of their musculoskeletal systems. It has been reported that overuse or repetitive trauma injuries represented approximately 50% of all paediatric sport-related injuries.[22]

Intensively trained elite young athletes competing and succeeding at international level had significantly higher injury rates than those competing at club, regional/county, or national level, a likely consequence of the intensity and duration of training necessary to compete at high level even at this age.[23] Conversely, a study on the effects of training at a young age (TOYA) reported a low prevalence of injury among the athletes studied than might have been expected.[24] A study on elite young athletes undergoing intensive training do not appear to be at increased risk of injury. On the contrary, data suggest a 'protective' effect of high-level organized sporting activity.[24]

However, it’s worth noting that comparisons of incidence rates and injury characteristics across studies should be viewed cautiously in light of methodologic shortcomings and study differences. The differing definitions of injury rates highlight that the measurement of “injury” needs a clear definition and a common language. These include also diversity of study populations, different periods of data collection and small sample sizes in some studies.

THE EFFECT OF AGE ON INJURY RISK

Age is an identified risk factor, with adolescents over 13 years being at greater risk of injury than younger children.[25] Malina[4] found that footballers below 14 years of age were at the greatest risk of injury due to maturity status. A study on incidence of injuries among elite French soccer players, Le Gall and co-workers[26] found players younger than 14 years incurred more injuries in training and sustained more growth-related overuse disorders. In boys’ sports, it is generally believed that the risk for injury would be greater among older boys because they are faster, heavier, and stronger and they generate more force on contact.[14] Older advanced-level gymnasts attempt more complex and difficult skills and accumulate greater exposure to training, perhaps related to overuse injuries.

However, chronological age (CA) is of limited use in the assessment of growth and maturation and the need to assess maturation is of primary interest when dealing with children and adolescents.[27] Adolescents of the same chronologic age may vary considerably in biologic maturity status, and individual differences in maturity status influence measures of growth and performance during childhood and adolescence.[28] Growth is typically viewed as a quantifiable change in body composition, the size of the body as a whole or the size of specific regions of the body.[29] Biological maturation is an ongoing process that begins prenatally and continues through approximately the first two decades of postnatal life.[3]

BIOLOGICAL MATURITY ASSESSMENT

Non-invasive methods

Maturation is assessed in terms of status – level of maturation at the chronological age (CA) of observation, percentage of predicted mature (adult) height at the time of observation provides also an estimate of maturity status[30] and timing – CA at which specific maturational events occur. Though related, the two are not equivalent.[29] Tempo or rate of maturation is a related aspect but is difficult to estimate. Predicted maturity offset/time before age at PHV provides an estimate of timing.[31]

Maturity timing

Refers to the chronological ages when specific maturational events occur, frequently assessed by age at peak height velocity (PHV).[3,29]**(Figure 1)**

Age at peak height velocity (PHV) refers to the estimated CA at maximum rate of growth in height during the adolescent spurt, which begins with acceleration in rate of growth in height (take-off), continues to accelerate until it reaches a peak (PHV).[31] Historically, growth rates from individual height records were graphically plotted to identify when the peak occurred.

PHV can only be determined with a longitudinal study where regular height measures are taken and then plotted, to determine the growth velocity over time.

Limitations of predicted ages with youth athletes and potential for misclassification must be recognized.[31]

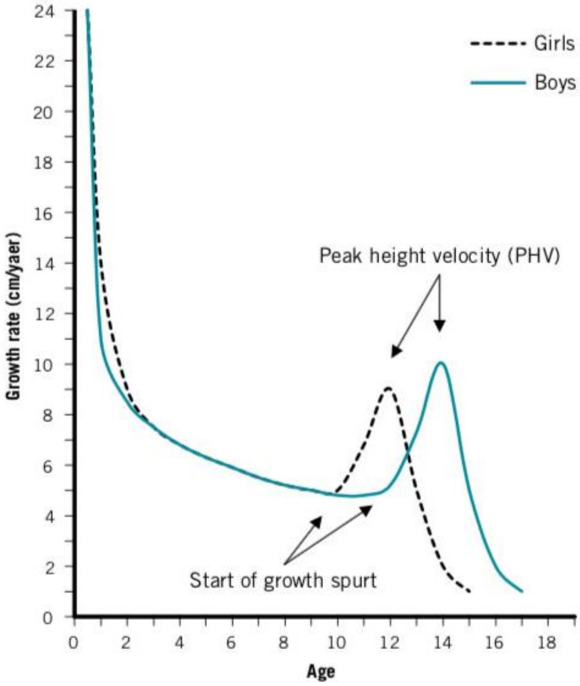


Figure 1. Curves for growth rate in boys and girls

Maturity tempo

Refers to rate at which the maturation process progresses. Children of the same age can vary significantly in their tempo of maturation with some individuals maturing well in advance or delay of their peers. Longitudinal data are required to measure tempo.[32]

Invasive methods

Skeletal maturity assessment

It can be achieved by the hand-wrist skeleton view on a standard radiograph. Changes in each bone from initial ossification to the adult state mark progress from immaturity to maturity. Maturity status is commonly specified by skeletal age (SA). SA is the most useful estimate of maturity status and can be used from childhood into late adolescence.[28,33] Major limitations are the costs, the minimal radiation (0.001 millisievert) and the need for qualified staff knowledgeable of assessment protocols, limitations and interpretations.[31] The assessment methods were criticized as most of the reference samples were from the United States or West Europe. It has also pointed out gaps in the research, such as few studies on different ethnicities, and no studies considering socioeconomic differences.[34]

Three methods for estimating SA are used:

Greulich-Pyle (G&P)

The G&P method is based on matching the child's hand radiograph to standard plates provided by the G&P atlas; thus, this method compares the hand's general maturational status. The population providing the G&P standard atlas were originally North American Caucasians of "good" socioeconomic status in 1938.[35] Full maturity considered to be 18 years of age.

Tanner-Whitehouse

In contrast to the G&P atlas, the TW method undertakes an assessment and scoring of skeletal maturity for each individual hand and wrist bone. Data provided by the Harpenden Longitudinal Growth Study enabled the TW method's development. In 2001, the TW3 method replaced the TW1 and TW2 methods as a result of documented secular change (as stated by the authors). The data that formed the TW3 method was collected from European and American Caucasian children of average socioeconomic status during the 1980s and 1990s. Full maturity considered to be 16.5 years of age.

Fels method

Method of assessing skeletal maturity was based on children enrolled in the Fels Longitudinal Study of Growth and Development, from 1932-1977. Fels method is the only one of the three that uses objective data in the form of measurements of the epiphyseal plates and the resultant ratios.[28,30]

A posterior-anterior x-ray of the left hand is used which includes approximately 3cm of the radius and ulna.[30]

The Fels differs from other methods for the inclusion of the ratios of the linear measurements of the epiphysis and metaphysis of the radius, ulna, metacarpals and phalanges of the first, third and fifth fingers. It also considers the development of the pisiform and adductor sesamoid of the first metacarpal.

The values for the measured ratios and grades of the maturity indicators are entered into a computer program that calculates a SA with a standard error of assessment.[28] Malina et al.[36] reported that SA is the gold standard of biological age assessment and that Fels method for SA measurement which has an advantage over other methods.

Only skeletal maturation spans infancy through adolescence; other indicators are limited to puberty/adolescence.

IMPLICATION OF GROWTH AND MATURATION

The selection, development, and progression of youth elite athletes is influenced by growth and maturation.[37,38] Therefore, a selection bias toward early maturing boys is evident from 12 to 13 years and increases with age and competitive level in youth soccer.[39]

At Aspire Academy, training programs are scheduled according to chronological age group and not, for example, maturity category. An established variability between athletes in height, weight, power, speed and agility will result in selecting athletes in advanced maturity. These differences in maturity and development can be as much as three to four years for boys of the same chronological age.[40]

It has also been shown that boys born early in the selection period are more likely to succeed in football than those born towards the end of the selection period.[41] This bias is said to be a result of the selection policies at youth level and could result in bias in the adult game.

THE IMMATURE SKELETON- REASONS FOR CONCERN

The skeletal uniqueness of children is the essence of their physical vulnerability to repetitious microtrauma. Sites of vigorous musculoskeletal development in long bones and their musculotendinous attachments are the specific areas of potential sports injury.[42] The physis, as the weakest part of the bone, is a site highly prone to injury in youth athletes[9] **(Figure 2)**. An increase in the rate of growth is accompanied by structural changes that result in a thicker and more fragile plate.[43] The adolescent growth spurt is a unique time in development that makes adolescents more susceptible to (growth related) injuries.[44] The musculotendinous junction tightens as lengthening bones impart more tension, and coordination is lacking.[14] Maturation status has been suggested to have an influence on injury characteristics.[26,45] In an unpublished data Materne et al reported that ~ 88% team- seasons events were growth-related conditions and ranked second after contusions. Price and coworkers[20] reported that typical chronic lesions of youth players are traction apophysitis such as the Osgood-Schlatter, Sever or Sinding-Larsen-Johansson disease.

Previous studies showed that youth athletes are at a higher injury risk particularly between the year before peak height velocity (PHV) and the year of PHV[46], and that the adolescent growth spurt represents a time of increased risk for sports injuries [47], especially for overuse injuries.

In a study on adolescent soccer players, Materne and coworkers[48] found that U15 players showed a peak incidence of injuries with little difference in the oldest age group. This peak may be explained by the fact that U15 age group corresponds to the average of APHV (14.3 years) of the study cohort.

Overuse injuries, term entrenched in the vernacular of sports medicine[49], are common in growing athletes and although often self-limiting, these injuries cause significant discomfort and often interrupt training for a long time.[7,50]

Apophyseal injuries are more common during sport activities. Stress related apophyseal injuries affecting young athletes involved in a variety of sports have been reported. Osgood- Schlatter and sever's disease both described as chronic apophysitis account for a staggering 18% of all adolescent overuse injuries reported in the literature[47] **(Figure 2)**.

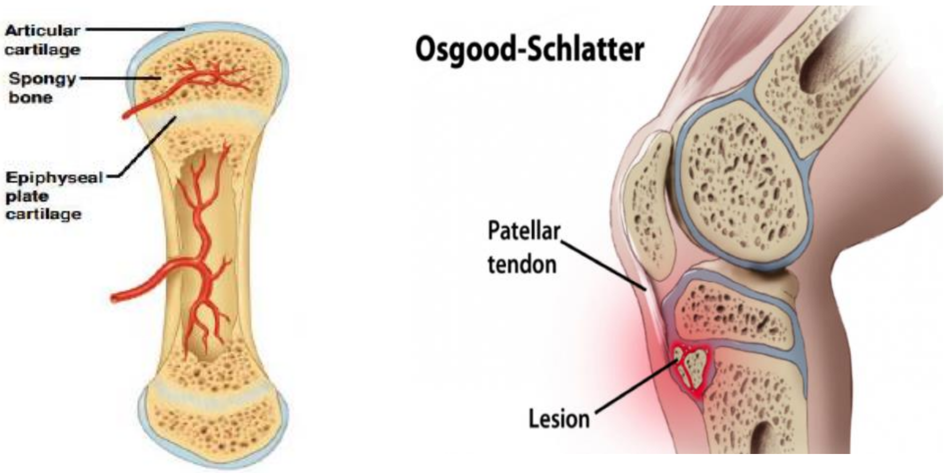


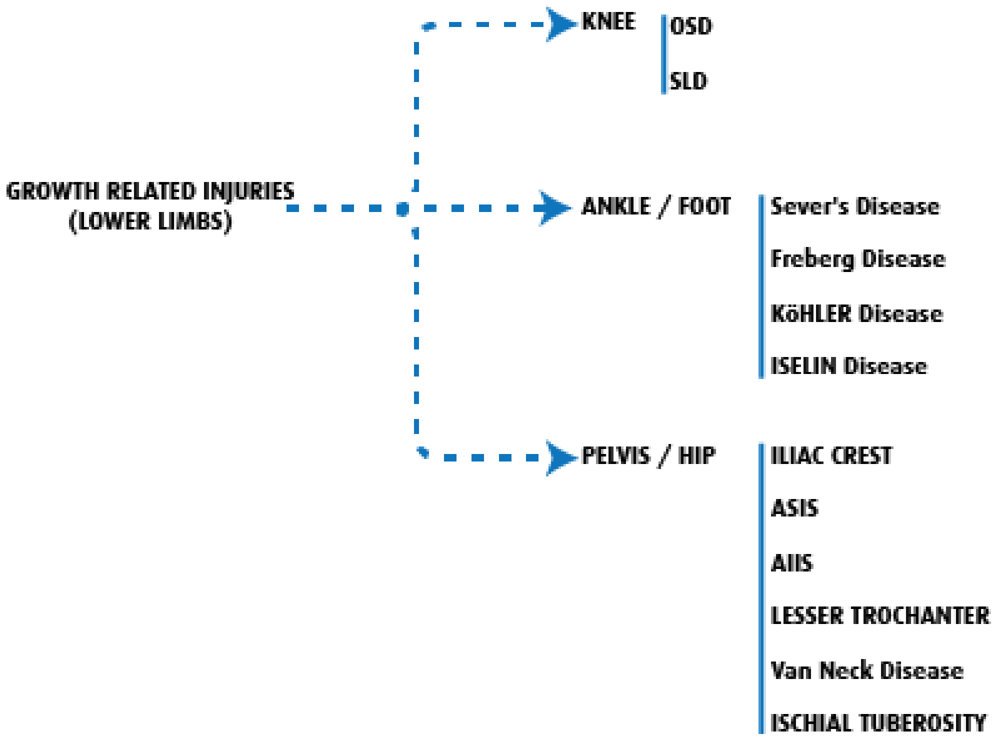
Figure 2. Schematic representation of endochondral bone formation. Skeletal maturity is mainly assessed by the degree of development and ossification of the secondary ossification centers in the epiphysis; and knee (ATT) apophysitis

Disproportionate training and repetitive loads hastened by peculiar and immature skeleton and often inadequate recovery frequently disrupt adolescent progress by growth related injuries.

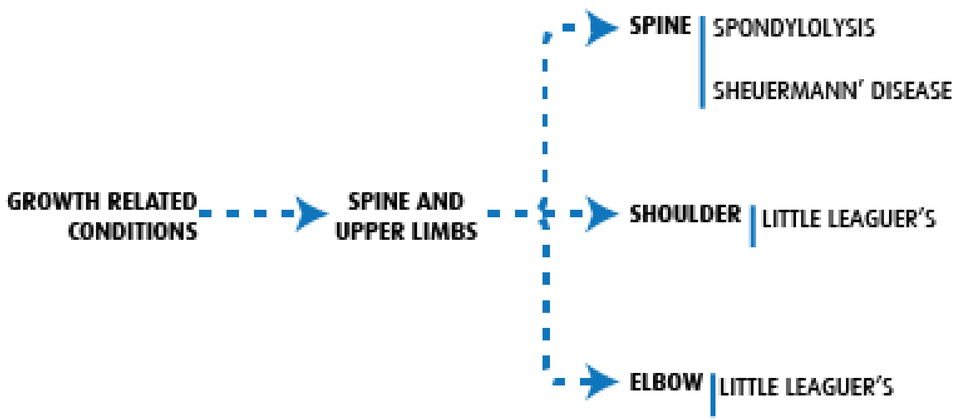
A schematic and elaborated illustration of most growth- related injuries linked to physical activity is lacking in the medical sports medicine references and paediatric annals. Only sporadically selected diseases as Osgood-Schlatter were investigated and explained.
A clear distinction should be made between:

(1) **Traction epiphyses** (or apophyses) (Map 1a, 1b) located at the site of attachment of major muscle tendons to bone and are subjected primarily to tensile forces. As a result, acute or chronic injuries affecting traction growth plates are not generally associated with disruption of longitudinal bone growth. Overuse apophyseal conditions, such as Osgood-Schlatter disease, Sever's disease, and medial epicondylopathy (little leaguer 'elbow), are common in young athletes and may be the source of significant discomfort and time lost from training.[9]

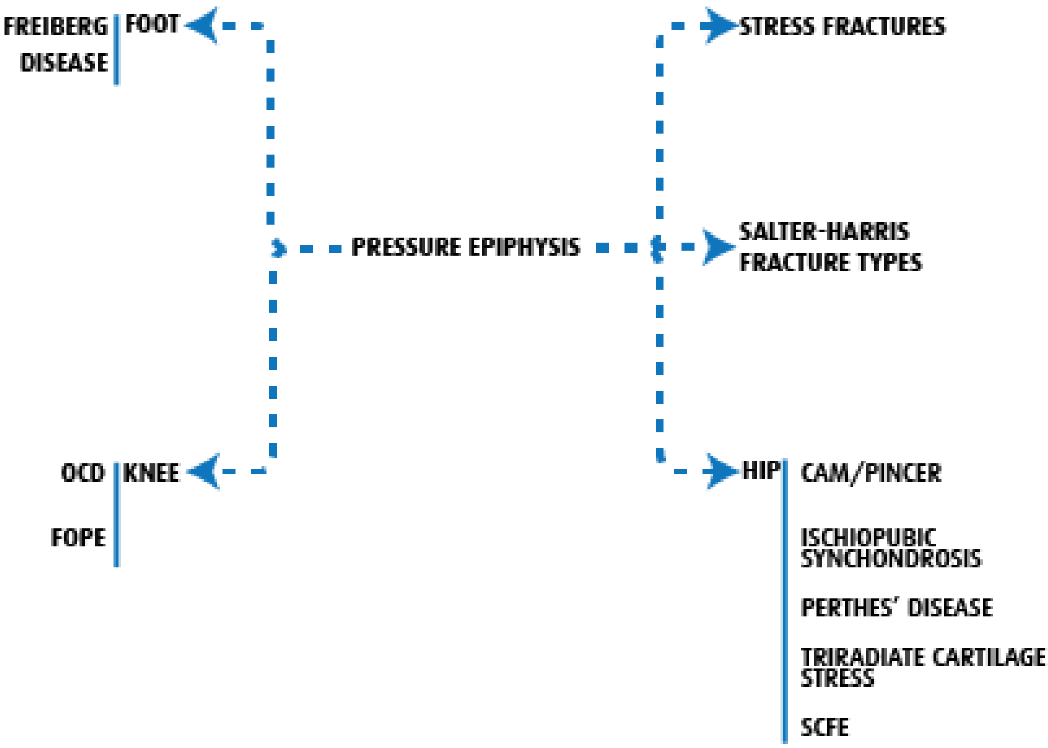
(2) **Pressure epiphyses** (Map 1c) situated at the end of long bones and are subjected to compressive forces. Growth plates, injury to pressure epiphyses and their associated growth plates may result in growth disturbance. Healthcare providers involved with adolescent athletes should be cognizant about pressure epiphysis as this may produce irreversible damage to the growing cells, resulting in growth disturbance. A referral to a specialized center is advisable.



Map 1a: Growth related injuries (Lower limbs)
***Legend:** OSD, Osgood-Schlatter disease; SLD, Sinding-Larsen disease; ASIS, anterior superior iliac crest; anterior inferior iliac crest*



Map 1b: Growth related injuries (Upper limbs)



Map 1c: Pressure epiphysis
Legend: OCD, osteochondritis dissecans; FOPE, focal periphyseal edema; SCFE, Slipped capital femoral epiphysis

Literature assessing the relationship between injury occurrence or severity and maturity status is lacking and largely overlooked in the medical and sport science literature. Only few published studies, mainly in soccer, seldom in multisport but, to the best of our knowledge, not in Arab adolescent elite athletes.

Sport participants with generalized joint laxity (GJL) have an increased risk of knee joint injury. Conversely GJL may be protective against injury in some limited contact and noncontact sports. There is a paucity of research pertaining to the impact of GJL and Beighton score (BS) changes on injury occurrence experienced by adolescent athlete.

1. Generalized joint laxity (GJL)

The range of movement at a joint varies between individuals. Reasons for this include inherited collagen structure in the joint capsule and ligaments, inherited shape of the bony articulating surfaces and neuromuscular tone which may be acquired and is modified by training.[51]

Joint hyperlaxity may be advantageous in certain sports and often recommendations for adolescent athletes with joint hypermobility include participation in noncontact activities only.[52] Conversely, Murray[53] recommends full involvement in sporting activities for pain-free hypermobile individuals. However, generalized joint laxity (GJL) is associated with joint injuries.[54] The decline of the Beighton score as a proxy measure for joint hyperlaxity as we age is aligned with the general belief that GJL lessens with aging and growth.[55] According to Singh and co-workers[56] in a study on an Australian population, Beighton scores varied across the lifespan and were significantly influenced by age. Many studies reported a significant decline in joint laxity from the age of 14 years. Reports as to why such a difference might exist around this age are thought to pertain to hormonal changes and puberty affecting joint mobility.[57] It has been proposed that the growth spurt may also increase susceptibility to growth plate injury by causing an increase in muscle-tendon tightness about the joints and an accompanying loss of flexibility.[9,48] Information about youth athlete growth history should, therefore, be assessed because peak growth velocity presents a risk factor for injury, as the transient passive elongation of soft tissues over actively elongating bone leads to temporary inflexibility and muscle imbalance and an increased risk of injury.[44]

Generalized joint laxity indicates a generally higher range of motion (ROM) than the mean ROM of the general population and has been purported as a risk factor for knee ligament injury.[54]

A number of questions may be posed about the relationship of hypermobility to clinical musculoskeletal complaints e.g. does the overall degree of hypermobility and its proxy Beighton score correlate with the occurrence of injury and injury type in an adolescent population? Any impact of sport category on injury risk? And does specific age or age group influence GJL?

According to Singh and co-workers[56]; Hakim and Grahame[58] and Simmonds and Keer[52], Beighton scores were also significantly influenced by ethnicity.

To our knowledge no studies have been conducted on adolescent elite athletes from Arabic population about the effect of hyperlaxity during the practice of structured and organized training.

There is emerging moderate evidence for a relationship between training load applied to an athlete and the occurrence of injury[59], however most studies were conducted on adults.

2. Training Load

Talent development programs should be maximizing individual development, while minimizing risk of injury. However, whether this is actually the case remains unknown.[60] Training contents and intensities should be adjusted based on the individual development of the athletes. It has been suggested that quality as well as the amount of training may influence injury rates.[61] It has been observed that associations exist between external load and heightened injury risks[62], however such evidence emanated mostly from studies on adult athletes. However, in order to effectively adapt and monitor the training process, it is necessary to determine the external load, but also be aware of the internal physiological response of the load on the individual.[63]

To help determine whether athletes are successfully amassing the necessary physical stimuli that is required for physiological adaptation, monitoring training load has become a vital cog in the training analysis process[64] Monitoring training load provides practitioners with an understanding of how players are adapting to the demands of training and match-play and provides insight into players who may be over or under reaching.[64,65]

By breaking down the training load into the internal and external load, practitioners can measure the physiological stress the players are exposed to by the prescribed training.[63] The external load refers to "the work completed by an athlete, measured independently of his or her internal characteristics".[66] Although quantifying the internal load as the product of the rate of perceived exertion (RPE) (10-point modified Borg) or heart rate (HR) indicator of internal response to training, presents practitioners with an indication of how an athlete is adapting to the physiological stress of a prescribed physical stimulus, the external load enables practitioners to establish whether specific performance outcomes are being completed by everyone.[66,67]

The process of monitoring the external and internal load has become significantly more accessible in recent years due to the vast improvements in monitoring technologies. Global positioning systems (GPS), time-motion analysis and Heart Rate (HR) monitoring software are now all commonplace in elite-level sport, and they provide great insight into the external and internal responses to training load. Monitoring HR is commonplace across all sporting disciplines and provides one of the most reliable internal indicators of exercise intensity and fatigue.[68,69] In order to reduce the risk of injury and to increase the fitness benefits a combination of monitoring HR response and GPS metrics would provide greater insight into the extent of the external (GPS) and internal (HR) demands of exercise in professional athletes. A substantial amount of research mostly on adult participants has tested the relationship between training load and injury. In the past 5 years, a total of 38 studies from as many as 24 different research groups, and 11 different sports have demonstrated that rapid increases in workload and low chronic workloads are associated with greater injury risk.[70]

In respect of an academy environment, youth athletes are frequently transitioning too rapidly to higher levels of training and competition demands during adolescence.[71] Deehan et al.[72] stated that an increased participation in sports predisposes the immature skeleton to injury.

Adolescent athletes are on journey to adulthood and their development should be seen always as a long-term project.[73] Long-term athlete development (LTAD) model specifically indicated the interval of PHV as the reference for programming training protocols. Training of the young sports performer should align with optimal periods of development which are generally termed as "windows of trainability".[71]

A postulated awkwardness might be manifested by boys and girls in the pubertal stage when the growth spurt is maximal, causing them to exhibit a plateau in performance or to demonstrate less accuracy and speed in the motor tasks compared to boys and girls in the prepubertal stage.[74]

'Catch them young' philosophy is tainted by the psychological and physical casualties which result from youngsters being pushed too hard too soon.[42]

It seems reasonable to focus on load management during critical phases, exposing young athletes to varying movement patterns and ensuring safe progression with sufficient rest and recovery.[3]

A review of the scientific literature revealed that research on the impact of training load on injury risk in adolescent athletes is largely overlooked and that most evidence emanated from studies on adults. Training load quantification and monitoring and adolescent athletes' responses to it is imperative to maximize the likelihood of optimal athletic performance, to determine normative sports-dependent values and to limit the injury risk.

The choice of appropriate method of training load quantification and monitoring will depend of the athlete sport category, practicality of the method and related wearable and the targeted information to collect either by the performance enhancement team and/ or the medical staff. As such information is lacking at Aspire Academy, an in-house pilot study is warranted to investigate the association between load and injury risk in our adolescent population and to find specific sport- dependent acute-chronic workload ratio (ACWR) "sweet spot" and to reflect on other reliable monitoring methods such as RPE.

YOUTH SPORTS AND INJURY PREVENTION

"The man and the model": Sequence of prevention

Leading scientific experts have proposed a very simple and efficient model to organize sports injury prevention initiatives.[75] Van Mechelen proposed the well-known sequence of injury prevention research in four steps in 1992. This is historically known also as "sequence of prevention" and consisted in injury surveillance, identification of risk factors and implementation of prevention strategies. Measures to prevent sports injuries do not stand by themselves. They fit in as integral component of what might be called a 'sequence of prevention'. (Figure 3). At the outset, the problem must be identified and described in terms of incidence and severity of sports injuries, then intrinsic and extrinsic risk factors should be investigated, a plan for injury mitigation should be proposed with an appraisal of its effectiveness through the repetition of the first step of the sequence.

Figure 3: The 'sequence of prevention' of sports injuries (Reproduced and adapted from van Mechelen www.anatomist.us with permission)

1. Step one: Extent of the problem

Little is known about injury epidemiology among young elite athletes.[76] So far apart from football, there is only few studies that focused on other sports.

The incidence and severity of the sports injury problem need to be established as a first step of injury prevention.[25]

The extent of the sports injury problem is often described by injury incidence and by indicators of the severity of sports injuries. Sports injury incidence should preferably be expressed as the number of sports injuries per exposure time (e.g. per 1000 hours of sports participation) in order to facilitate the comparability of research results.[77]

2. Step two: Identification of underlying mechanisms and risk factors

The factors and mechanisms which play a part in the occurrence of sports injuries have to be identified.[77] Historically, based on traditional biomedical and pathophysiological etiology, the cause–effect paradigm has been applied widely in sports injury research, focusing on identifying risk factors for injuries.[78]

Finch[79] expanded the model to consider the context in which interventions are to be implemented to ensure uptake of the interventions in a real-world context through the Translating Research into Injury Prevention Practice (TRIPP) framework.(Figure 4)

Model Stage	TRIPP	Van Mechelen et al 4 stage approach [1]
1	Injury Surveillance	Establish extent of the problem
2	Establish aetiology and mechanisms of injury	Establish aetiology and mechanisms of injury
3	Develop preventive measures	Introduce preventive measures
4	"Ideal conditions"/scientific evaluations	Access their effectiveness by repeating stage 1
5	Describe intervention context to inform implementation strategies	
6	Evaluate effective of preventive measures in implementation context	

Figure 4. The Translating Research Into Injury Prevention Practice (TRIPP) framework *(Courtesy Caroline Finch)*[80]

The simplification of complex problems into basic units is the classical science method of analysis in the reductionism paradigm.[81] The multifactorial and dynamic nature of injuries has been recognized by distinguishing the intrinsic and extrinsic risk factors that lead to injury, yet in a sequential linear way.[82] Recently, Bittencourt et al.[81] introduced the concept of a web of determinants (i.e. risk factors), which implies a complex and dynamic system approach and moving from risk factor identification to injury pattern recognition. The complex nature of sports injuries arises the interaction among what is called "the web of determinants".

3. Step three: Introduction of prevention initiatives

Subsequent preventive interventions likely reducing the risk of injury in adolescent athletes are introduced, based on information of the second step. Preventive measures are important and are worthy of consideration. Involvement of sport coaches is important: training loads should be reduced during the rapid growth period. Increased exposure training time should be revisited.

Knowing that physeal injuries are exclusive to skeletally immature individuals, would suggest that modifiable and nonmodifiable risk factors are specific to youth athletes[47,83] and put into place appropriate preventive measures. Health care providers should also promote communication with the young athlete's coach, to identify promptly symptoms related to growth related injuries, and start treatment as soon as possible.

Ekstrand et al.[84] reported that the quality of internal communication within a team was correlated with injury rates and training attendance.

Based on the etiological factors and the identified mechanisms (e.g. maturity level) recent effort to address individual differences in biological maturation among youth sport and training is labeled bio-banding. Bio banding is a process whereby youth soccer players are grouped on the basis of maturational rather than age-based criteria.[85]

This bio-banding appears to be most relevant during puberty (age 10–16 years in boys), when maturity-associated differences in body size, function, and physiological adaptations are greatest.

It should be considered by the coaches that chronological age will not always correspond with a boy's biological age and this must be taken into consideration when planning a training program.

4. Step four: assessment of the preventive measures

An appraisal of the effect of measures introduced in step three must be conducted by repeating the first step. The newly found injury extent and other variables e.g. absence days, rate of injury recurrence, athletes' availability could be an indication of the effectiveness of the prevention measures.

There are a number of limitations, however, associated with this four-stage approach and the extent to which it has been implemented in practice (methodological issues as self-reported information, univariate analysis etcetera). A serious limitation, the model does not consider the research into implementation, once a prevention measure has been proven to be effective[80] as good efficacy or effectiveness research, alone, does not ensure uptake of the interventions and hence prevention of injuries. "The real-world'' context should be considered as an appropriate adjunct to van Mechelen prevention model.

BACKGROUND AND AIMS

Little is known about injury epidemiology and injury mechanisms among young elite (non-soccer) athletes.[76] There is a paucity of epidemiological data on the extent and determinants of injury in highly trained adolescents in respect to an academy environment. McBain et al.[86] found that only 14% of the studies aiming to investigate different preventive strategies, included children and adolescents under the age of 18 years. Studies of youth injuries prevalence or sports participation in athletes who start systematic training in an academy environment during or prior to adolescence are scarce.[23] As we enrolled in our studies a unique population of highly trained youth athletes, it is important to describe the main characteristics of this dissertation' studied population. Given the possible interaction between intensive training and growth during adolescence[87], some adolescent athletes may be particularly vulnerable to repetitive micro-traumatic injury.[88] Data on youth soccer players reported substantial greater hazard ratio during peak height velocity, suggesting that somatic maturation is a potential risk factor[48] and period of heightened risk has been indicated during peak height velocity (PHV)[46]. Johnson and colleagues[41] recommended that future studies should further analyse how maturity status and maturity timing may affect different types of injury (e.g. growth-related and overuse injuries). Studies have consistently demonstrated that hypermobility is more prevalent in younger age groups.[89] Generalized joint hyperlaxity (GJL) has been suggested to play a role on the incidence of musculoskeletal injuries in many sports activities.[90] Unanswered questions about the correlation between generalized joint laxity, injury occurrence and injury type in adolescent Arab elite athletes and if specific age has an effect on Beighton scores. Previous studies have shown links between training load and injury in adolescent populations.[59,73] Training load monitoring is fundamental and an opportunity to learn, reflect and prescribe an appropriate training for youth. Clinicians may effectively minimize injury risk by monitoring applied loads across all adolescent sports participation.[91]

Monitoring training load provides practitioners with an understanding of how players are adapting to the demands of training and match-play and provides insight into players who may be over or under reaching.[64,65] It is important to note that the values of ACWR, and its derived sweet spot are not 'golden' numbers, they will not apply to every athlete in every sport.

At Aspire Academy, Sports excellence center aiming to develop champions in different sports and sports event with a distinct focus on football excellence. It is important to conduct some research to investigate the impact of load on injury risk in an adolescent population, relate it to sport category and to determine the injury risk ranges; with the best-case scenario being an in-house study of our athlete population. To our knowledge, no research has been done to date to determine the injury risk ranges within our population.

Understanding the cause of injury is required to advance the body of knowledge to mitigate sports injury rate among adolescent athletes.

The aim of the current dissertation is twofold.

I. To determine the incidence, prevalence and injury profiles sustained by youth in multisport.

II. To prospectively investigate suggested intrinsic and extrinsic risk factors (e.g. maturity, joint laxity and training load) for the development of sports injury in adolescent highly trained athletes.

AIM I: To determine the incidence, prevalence and injury profiles sustained by youth in multisport

Aspire Academy for Sports Excellence: Participants singularity

Since its establishment in 2004, Aspire Academy is mandated to provide sports training and education to students (aged between 12-18 years) with sporting potential, in an exceptional learning and sporting environment. The overall purpose is to have Qatari athletes that are well prepared in their sport, and academically, to meet the needs of the Qatari society and realize its aspirations in international sports competitions.

The selection follows a three-tiered talent identification process consisting of a bronze phase of mass screening; a more competitive silver phase and finally a gold phase, where the best potential sporting talents with the focus and desire to achieve a sporting dream are nominated for full Aspire Academy scholarships.

All the athletes participated on average in ~16h of combined specific training and competition per week (six to eight specific training sessions, two to three strength and conditioning sessions).

Aspire Academy student-athletes are developed through comprehensive athlete portfolio management, whereby coaches, educators, support service, service providers and management personnel actively cooperate to achieve an integrated athletic development model e.g. long-term athletes' development (LTAD) program based on specific and measurable performance outcomes.

Injury epidemiology studies in youth athletes are a prerequisite for the development of prevention strategies[76]. Therefore, in **chapter two**, we examined the injury incidence in highly trained multisport (non-soccer) adolescent athletes using an injury surveillance record to prospectively collect injury data from 166 athletes during the seasons from 2009 to 2014.

In our academy training setting, recognized as a high-performance sports environment, with its structured weekly training, the demands of high-level sport are imposed on athletes during periods of growth and maturation, thus the secondary aim of our first study was to investigate the association of training exposure and the likely risk of injury among adolescent athletes.

AIM II: To prospectively investigate suggested intrinsic risk factors (maturity and joint laxity) and extrinsic risk factor (training load) for the development of sports injury in adolescent highly trained athletes.

In chapter three part one and chapter four we examined (1) the relationship between maturity level assessed using both invasive and non-invasive methods and the development of sports injury, and (2) the association between generalized joint laxity and injury rate in adolescent athletes.

In chapter three part two the injury characteristics of the cohort in relation to the suggested intrinsic risk factor of maturation is investigated.

The appropriate study design for risk factor analyses is a prospective cohort study, where both hypothetical candidate intrinsic risk factors are measured at baseline and the cohort followed prospectively over four seasons to record injuries in a defined period of time.[92] The more advanced model to study risk of injury is the Cox proportional hazards regression model.[92]

In chapter five a pilot study was conducted to examine the relationship between training load, quantified by HR monitoring, as a suggested internal load monitoring tool and injury among adolescent athletes. Such study could serve an important role when determining the most appropriate trial design and as in-house study of our athlete population. Such trials are intended for use in a larger program of research of informed load management which is warranted to mitigate the burden associated with growth- related injuries and to determine the optimal workload and lowest relative injury risk.

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Chapter Two

COMPELLING OVERUSE INJURY INCIDENCE IN YOUTH MULTISPORT ATHLETES (A 5- YEAR COHORT STUDY)

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ABSTRACT

The present investigation was carried out to examine the incidence and pattern of injuries in adolescent multisport athletes from youth sports academy. Injury data were prospectively collected from 166 athletes during the seasons from 2009 to 2014. A total of 643 injuries were identified, 559 (87.0%) were time-loss injuries. The overall injury incidence was 5.5 (95% confidence interval CI: 5.1–6.0), the incidence of time-loss injuries was 4.8 (95% CI: 4.4–5.2), the incidence of growth conditions was 1.2 (95% CI: 1.0–1.4) and incidence of serious injuries was 0.6 (95% CI: 0.5–0.8) per 1000 h of exposure. The prevalence of overuse injuries was 50.3%. Growth conditions represented 20.0%. Most of the injuries (67.0%) involved the lower extremities, and both foot and ankle were the most predominant injured body parts (22.0%). Knee injuries were mostly from overuse (50 vs. 23, $p = .02$), whereas foot and ankle injuries resulted from an acute mechanism (94 vs. 31, $p < .0001$). Minor and moderate injuries accounted for 87.0%. Muscle, tendon and osteochondrosis injuries accounted for 52.0% of all injuries. Comparing groups, squash sport was having the highest injury incidence (8.5 injuries per athlete). Higher exposure was associated with greater overuse relative risk (RR = 1.03, 95% CI: 1.01–1.014, $p < .001$). In conclusion, the results of this study identified a high incidence of injuries in this youth sports population. Striking was the prevalence of overuse injuries of 50%, which suggests the need for injury prevention protocols for adolescent highly trained athletes.

Keywords: *Youth, training, injury and prevention*

INTRODUCTION

Physical activity improves the overall health status of adolescents. However, the growing involvement of adolescents in sports gives rise to concerns regarding the risk of sports injuries.[1] Injuries can counter the beneficial aspects related to sports activities, especially if an athlete is unable to continue to participate because of long-term consequences of injury.[2,3] Compared to other age groups, youth are more involved in sports activities and have a higher rate of the sport injuries.[4] Sport participation in childhood and adolescence is an established cause of acute and overuse injuries. Longer exposure to training is one of the main risk factors for injury, and constant exposure to repetitive athletic actions and overload place the integrity of bodily structures at risk.[1,5] Bergeron et al.[6] reported that extensive high intensity sports training can alter growth rates. Higher training volumes have consistently been shown to increase the risk of overuse injury in multiple sports,[7] and load has been shown to be one of the most important predictors for injury. The determination of injury rates based on time-at-risk exposure data is also important.[2] Little is known about injury epidemiology among young elite athletes.[8] Pressured adolescent athletes in different disciplines across all sports are often halted by sports injuries with varying time-loss (TL).[9] The incidence and severity of the sports injury problem need to be established as a first step of injury prevention.[10] Therefore an injury epidemiology study in youth athletes is required for the development of prevention strategies.[8] The primary aim of this study was to examine the injury incidence in highly trained adolescent athletes using an injury surveillance record to prospectively collect injury data. The secondary aim was to investigate the association of exposure and the risk of injury occurrence.

METHODS

A total of 166 male adolescent athletes 12–18 years from different sports (track and field [n = 84], squash [n = 18], table tennis [n = 20], fencing [n = 20], gymnastics [n = 13], swimming [n = 4], golf [n = 3] and shooting [n = 4]) were included in this prospective study. Twenty-one participants were being followed-up for 5 years, 28 for 4 years, 42 for 3 years and 33 for 1 year. Athletes were considered eligible if they were granted a six-year scholarship by the Middle Eastern Youth Sports Academy, which combines sport training and school (**Figure 1**).

Data from medical records were used to document all sports-related injuries during the study. Every athlete had direct access to medical facilities of the academy. Each different sports group had a dedicated full-time physiotherapist and a full-time employed medical doctor was available at the sporting academy. The medical record used an injury reporting system, based upon the football injury reporting system described by Junge et al.[11] and Sport Medicine Diagnostic Coding System.[12] Information was gathered concerning all injuries related to sports activity, including several related variables (e.g. type, location, affected structure, mechanism [acute vs. overuse], date of injury, TL and severity). Injuries not sustained in the context of the sport program or any data related to sickness or other general medical conditions were excluded from use in this study.

Written informed consent was sought and obtained from all participants and their parents. The study was reviewed and approved by the Institutional Review Board for Human Subjects, by the local research ethics committee (SCH-ADL-070) and conformed to the recommendations of the Declaration of Helsinki.

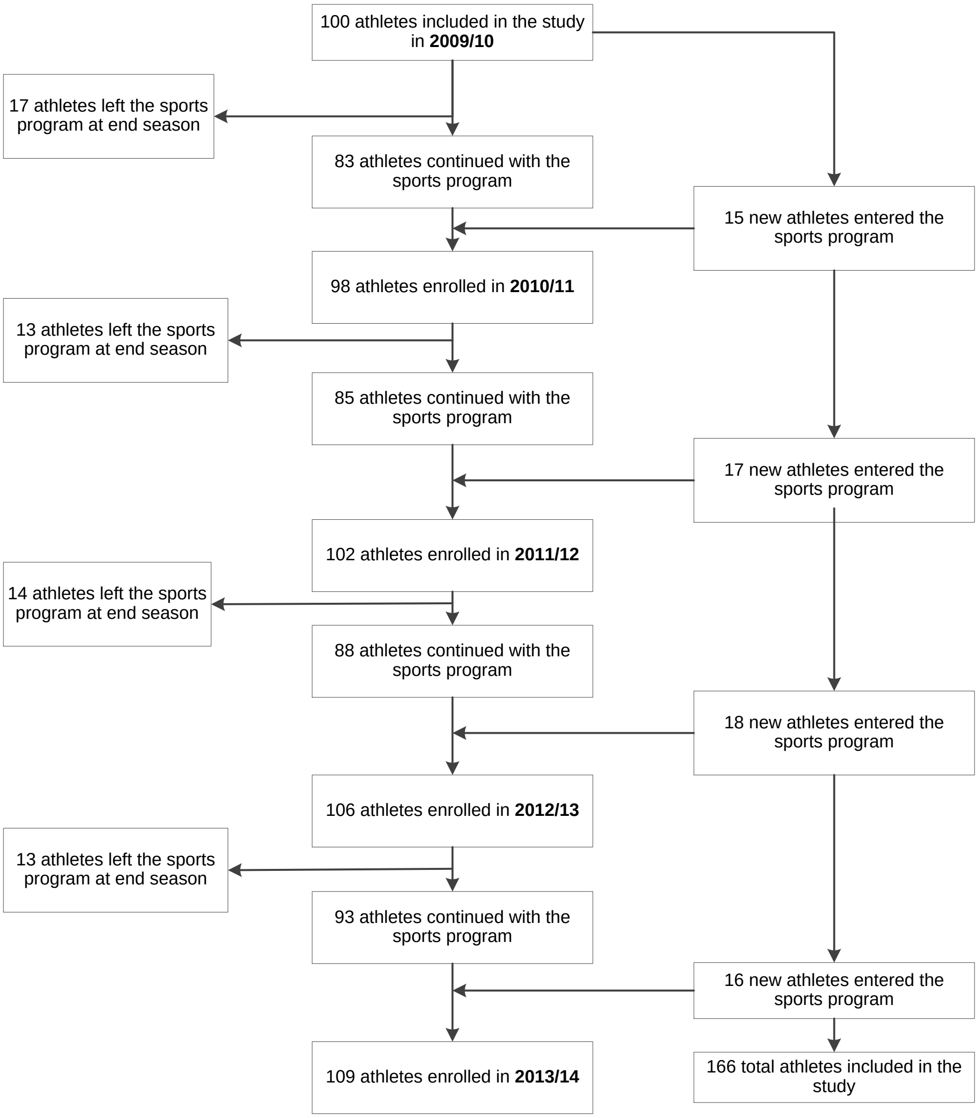

Figure 1: Flowchart describing the inclusion and flow of participants throughout the study

DEFINITION OF INJURY

An injury was recorded as a physical complaint requiring the attention of the medical staff resulting from either a sports training, a strengthening and conditioning training or from a competition. Injuries were divided into time-loss injuries and no time-loss (NTL) injuries. A visit to physiotherapy unit, requiring a clinical examination and/or treatment without missing full training session or competition was described as "Medical attention" with NTL injury. A visit resulting in an athlete being unable to fully take part in training session or competition, the following day(s) was labelled as a TL injury.[13] The lay-off was calculated by the number of days missed from the date of injury (Day zero) until the day before the return to full participation in training availability. A traumatic injury was defined as any injury resulting from a specific and identifiable mechanism, including contact and non-contact circumstances with acute onset.[14] Overuse injuries were defined as injuries resulting from insidious onset without a recognizable mechanism.[15] Growth conditions injuries are unique to young athlete and resulted from an increase in the involvement in sports activities by children and adolescents.[16]

Injury severity was defined, based on days of absence from usual sport participation, as slight (1 day), minimal (2–3 days), mild (4–7 days), moderately serious (8–28 days), serious (>28 days–6 months) or long-term (>6 months) in accordance with Timpka et al.[17] definition.

EXPOSURE

Training diaries were collected, and expressed in hours and minutes, on a daily basis by respective coach. On average, every student, irrespective of the sport they have been selected for, were given 8 training sessions/week (5 technical, 2 strength and 1 conditioning), with a duration of 120 min/session; total of 16h per week. Training exposure data from ill athletes were not accounted. The exposure periods (46 weeks) were during the school years, from mid-September until the end of June. The total training time is around 740 h per season per adolescent.

STATISTICAL ANALYSIS

Descriptive statistics were presented as frequencies, proportions (%) and incidence rates were expressed as number of injuries/1000 h of exposure with 95% confidence intervals.

The injury rates were described for each region independently, by injury type, injury severity and type of sport. Generalized estimating equations were used only for comparing the risk of injuries by sport type, injury type and severity as Poisson regression after accounting for individual exposure. For post hoc comparisons for injury type and sport type, Bonferroni correction was applied. Analyses were performed with IBM SPSS statistics v. 21. The results were presented with mean and standard deviation. The significance level was set at 5%.

RESULTS

The mean age of the athletes at the time of injury was 15.1 ± 1.9 years. Throughout the 5-season study period, 166 athletes were subjected to 116,473 h of training exposure time. From these 166 players, 152 (91.6%) reported one or more injuries totaling 643 injuries. The overall injury incidence was 5.5 (95% confidence interval [CI]: 6.4–7.4) per 1000 h exposure and accounting for 3.9 injuries per athlete. Of these, 559 (87.0%) were TL injuries with an incidence of 4.8 (95% CI: 4.4–5.2) per 1000 h exposure. The incidence of injuries with NTL was 0.7 (95% CI: 0.6–0.9) per 1000 h exposure. Overuse injuries accounted for 50.3%, from all the TL injuries. The overall growth-related injuries incidence was 1.2 (1.0–1.4).

Further details on injury incidence are presented in **Table I**.

Table 1: Injury incidence [a]

Variable	Injuries, n (%)	Exposure, h	Incidence/1000h (95% CI)
All injuries	643 (100.0)	116,473	5.5 (5.1-6.0)
No Time loss	84 (13.0)	116473	0.7 (0.6-0.9)
Time loss	559 (87.0)	116,473	4.8 (4.4-5.2)
Acute time loss	278 (43.0)	116,473	2.4 (2.1-2.7)
Overuse time loss	281 (44.0)	116,473	2.4 (2.1-2.7)
Growth conditions	140 (20.2)	116,473	1.2 (1.0-1.4)

Legend: [a] Incidence is given as the number of injuries per 1000 hours of exposure.

Location and diagnosis of injury

Most injuries with TL were located in the lower extremities (n = 329, 67.0%) and most often in the foot and ankle (22%, 95% CI: 17–27); knee; (13.0%, 95% CI: 9.0–17.0) and in hip and groin (10%, 95% CI: 6–13). Anterior thigh is predominantly affected by acute injury mechanism (p = .005). Overuse is the main mechanism of injury of lumbar spine. The knee was the most common region for serious overuse injuries (34.0%), while foot and ankle were the most common locations for the serious acute injuries, accounting for 22.0%. Further details on the distribution of injuries with TL are presented in **Table 2**.

Table 2. Incidence, Proportion, and Severity of injuries by body part and mechanism

Injured Region	No. of Time-Loss Injuries	Percentage of All Time-Loss Injuries (95% CI)	Incidence [a] (95% CI)	P Value Ratio	Serious Injuries [b] n (%)
Upper Limbs					
Shoulder	34	6 (3-9)	0.3 (0.2-0.4)		3/34 (9)
Acute	11	2 (0-4)	0.1 (0.1-0.2)	.040	3/11 (27)
Overuse	23	4 (2-6)	0.2 (0.1-0.3)		0/23 0
Hand &Wrist	57	10 (7-14)	0.5 (0.4-0.6)		3/57 (5)
Acute	39	7 (4-10)	0.3 (0.2-0.5)	.005	3/39 (8)
Overuse	18	3 (1-5)	0.2 (0.1-0.2)		0/18 0
Lower Limbs					
Hip/Groin	54	10 (6-13)	0.5 (0.4-0.6)		6/54 (11)
Acute	20	4 (1-6)	0.2 (0.1-0.3)	.057	2/20 (10)
Overuse	34	6 (3-9)	0.3 (0.2-0.4)		4/34 (12)
Thigh (Ant.)	29	5 (3-8)	0.3 (0.2-0.4)		4/34 (12)
Acute	22	4 (2-6)	0.2 (0.1-0.3)	.005	4/34 (12)
Overuse	7	1 (0-3)	0.1 (0.0-0.1)		0/34 0
Thigh (Post.)	48	9 (5-12)	0.4 (0.3-0.6)		6/48 (15)
Acute	23	4 (2-6)	0.2 (0.1-0.3)	.773	3/23 (13)
Overuse	25	4 (2-7)	0.2 (0.1-0.3)		4/25 (16)
Knee	73	13 (9-17)	0.6 (0.5-0.8)		20/73 (27)
Acute	23	4 (2-6)	0.2 (0.1-0.3)	.002	3/23 (13)
Overuse	50	9 (6-12)	0.4 (0.3-0.6)		17/50 (34)
Lower Leg	43	8 (5-11)	0.4 (0.3-0.5)		5/43 (12)
Acute	19	3 (1-6)	0.2 (0.1-0.3)	.446	1/19 (5)
Overuse	24	4 (2-7)	0.2 (0.1-0.3)		4/24 (17)
Foot & Ankle	125	22 (17-27)	1.1 (0.9-1.3)		24/125 (19)
Acute	94	17 (12-21)	0.8 (0.7-1.0)	< 0.0001	21/94 (22)
Overuse	31	6 (3-8)	0.3 (0.1-0.4)		3/31 (10)
Spine					
Lumbar	46	8 (5-12)	0.4 (0.3-0.5)		1/46 (2)
Acute	9	2 (0-3)	0.1 (0.0-0.2)	< 0.0001	0/9 0
Overuse	37	7 (4-10)	0.3 (0.2-0.4)		2/37 (5)
Thoracic	20	4 (1-6)	0.2 (0.1-0.3)		0/20 0
Acute	5	1 (0-2)	0.1 (0.0-0.1)	.025	0/5 0
Overuse	15	3 (1-5)	0.1 (0.1-0.2)		0/15 0
Cervical	7	1 (0-3)	0.1 (0.0-0.1)		0/7 0
Acute	3	1 (0-1)	0.0 (0.0-0.1)	.025	0/3 0
Overuse	4	1 (0-2)	0.0 (0.0-0.1)		0/4 0
Others c					
Other	24	4 (2-7)	0.2 (0.0-0.4)		1/24 (4)
Acute	11	2 (0-4)	0.1 (0.1-0.2)	.683	1 /11 (9)
Overuse	13	2 (1-4)	0.1 (0.1-0.2)		0/13 0
Total	559	100	5.0 (4.4-5.2)		74/559 (13)
Acute	278	50 (44-56)	2.4 (2.1-2.7)	.899	40/73 (55)
Overuse	281	50 (44-56)	2.4 (2.1-2.7)		33/73 (45)

[a] Number of injuries per 1000 hours of exposure; [b] Serious injury is an injury with reported absence of 4 calendar weeks ; [c] Chest/Trunk (n = 9, Elbow (n = 8), Forearm/Arm (n = 1)

In this study, the highest incidence of injury was sustained in squash athletes (8.5, 95% CI: 7.2– 10.0) and lowest in the fencing athletes (3.99, 95% Compelling overuse injury incidence in youth multisport athletes 3 CI: 2.85–5.43). Further squash reported higher overuse injuries (4.7, 95% CI: 3.8–5.6) compared to acute injuries (3.3, 95% CI: 2.6–4.1) which was also similar in other sports group (table tennis, fencing and gymnastics). It is only among the track and field group where the incidence rate of acute injuries (3.4, 95% CI: 3.0–3.7) was higher than the incidence of overuse injuries (2.4, 95% CI: 2.1– 2.7). **Figure 2** shows the incidence of TL injuries by sports group (injuries/1000 h). Most frequently injured body structures were muscle and tendon (30.1%), with an incidence of 1.67 (95% CI: 1.44– 1.92), and osteochondrosis (21.7%), with an incidence of 1.20 (95% CI: 1.01–1.42).

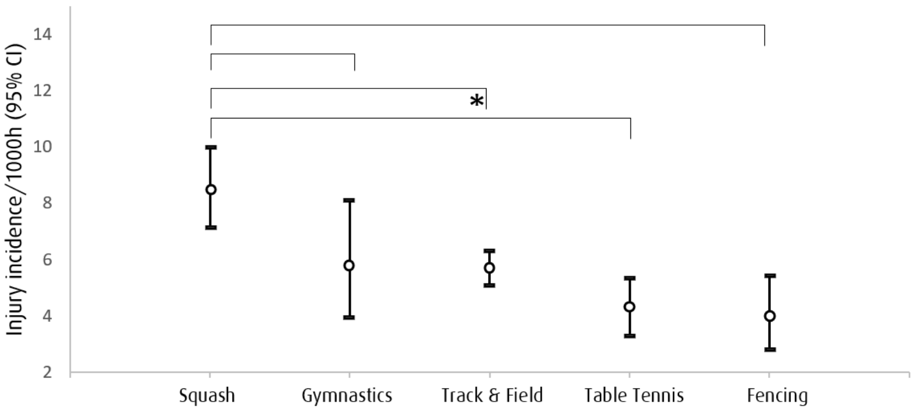

Figure 2: *Incidence of TL injuries by sports group (injuries/1000 h). *Incidence significantly higher than all other sports (p < .05).*

INJURY SEVERITY

Our results showed that the most reported injuries (53.0%) were minor. Within the minor injuries, the mild were most frequent, accounting for 21.0%, 34.4% of all injuries were moderately serious injuries, while serious injuries accounted for 13.0%.

Risk by volume of exposure, mechanism of injury and sports group

Training volume exposure was significantly associated with risk of injury. The relative risk (RR) was found 1.01 and can be interpreted as for every 10 h increase in volume of exposure training, the risk of injury increased by 1% ($p < .001$). Using fencing athletes as a reference, the RR of injuries in squash athletes was 2.15 (95% CI: 1.55–2.98, $p < .001$), gymnastics 1.37 (95% CI: 0.90–2.10, $p = .174$); track and field 1.35 (95% CI: 0.99–1.83, $p = .060$); and table tennis 1.04 (95% CI: 0.72–1.51, $p = .821$). Training volume exposure was significantly associated with risk of overuse injury. The RR of overuse injuries was found 1.03 (95% CI: 1.01– 1.014, $p < .001$).

DISCUSSION

The present investigation was carried out to examine the incidence and pattern of injuries in young elite multisport athletes. Major findings were the high rate of injuries with subsequent TL, the high rate of overuse injuries (50.3%), and high prevalence of growth-related conditions, and that most of injuries were minor and in the lower limbs.

In our study, the rate of injury with TL was 87% and an incidence of 4.8 per 1000 h of exposure. Beachy and Rauh[18] reported a rate of TL injuries of 45.1% with an incidence of 2.7 per 1000 athletic exposures. The discrepancy between the two studies may be explained by inconsistencies with respect to possibility of reporting bias. Beachy and Rauh (2014)[18] reported that some athletes may have had self-treated injuries that were not reported to athletic training staff. Therefore, approximation of the number of injuries with TL could have led to an underestimation of injury rates. Comparing our results with other investigations on elite youth soccer players, the prevalence of injuries with TL (87.0%) is higher than those previously reported (63.4%),[19] (41.4%)[20] and (66.5%).[21] The discrepancies between rates of injuries with TL in youth soccer players may be caused by differences in data collection methods, through the Short Message Service system,[19] or parents reports[20] which had the potential to lead to a significant underestimation of the number of injuries. These discordances may also be due to the urge demand to return to training and or competition soon after injury for soccer players.[21,22]

The prevalence of overuse injuries acquisition in the present study was 50.3%, and consistent with other studies in youth, where estimates of the proportion of sports injuries that are due to overuse ranging from 45.9% to 54.0%.[23,24] However, our finding was higher than previously observed in elite youth soccer players, 29.8%,[21] 22.9%[19] and 13.4%.[22] The reduced rates of overuse injury in soccer may be due in part to regular recovery periods within the annual calendar[13] but could be also attributed to the characteristics of the sport, contact and team sport versus individual sport, as the frequency and type of overuse injuries in elite young athletes vary by sport, and sports-related training and conditioning.[7] The higher incidence of traumatic injuries could be context-dependent, because contacts between players and teammates are generally more frequent in team sports.[25] The dissimilarities could be also due to data recording method as most studies[26,27] consider only overuse injuries if these are associated with TL and this most likely led to under-reporting overuse injuries.[28] It has been suggested that traditional injury registration methods, based on TL, underestimate the true rate and impact of injury.[29] Therefore, all complaints should be reported, regardless of TL, as a consistent method to capture overuse injuries.[30]

On this basis, our findings are a cause of concern and suggest that previously reported overuse injury rates in adolescent athletes may be substantially underestimated and advised that "any physical complaint sustained by a player" injury definition should be considered in future study methodologies.

The prevalence of growth-related conditions (20.0%) observed in this study, differs from previously reported studies where an incidence ranging from 0% to 16.8% was reported.[21,22,26] The discrepancies between studies are more likely attributed to our enhanced reporting of early signs of growth-related conditions through an implemented monitoring plan, instead of the usual athlete reporting complaints to the healthcare provider. Growth conditions injuries do occur more common during sudden growth periods.[31] These cause some concerns and require prevention strategies such as growth monitoring for long-term consequences.[20]

In our training centre, recognized as a high-performance sports environment, with its structured weekly training, the demands of high-level sport are imposed on athletes during periods of growth and maturation, which may have caused high rate of growth injuries. This is a compelling example where a closer look at injury inciting factors and prevention plans for youth athletes are needed.

The majority of injuries in our study were located in the lower extremity (67.0%), this result is roughly similar to the findings from a study at a middle school for multisport evaluation of injuries (70.0%)[18] but our result is lower to findings corresponding to other investigations on youth soccer players where lower extremity injuries were reported ranging from 83.4% to 86.0%.[19,22] These discrepancies may have depicted the difference between soccer injuries[32] and non-soccer injuries. Therefore, injury prevention measures should focus evenly on upper and lower limbs in non-soccer athletes. Foot and ankle injuries accounted for 22.0% and this is in line with similar reports figures (20.0%) of the National Collegiate Athletic Association. A possible reason for the vulnerability of the ankle to injury is reduced motor coordination and proprioceptive skills.[33] Measures to prevent acute ankle sprains could include stabilization exercises, bracing, foot muscle strengthening[34] and ensuring a good match between shoes and surface characteristics.[35,36] Also considering the evidence, there is consistency across the literature to support the preventative effect of multifaceted neuromuscular training programs inclusive of strength, balance and agility components in reducing the risk of lower extremity injuries in youth sport.[4]

Fortunately, most injuries were minor (53.0%). The results for injury severity are similar to those reported for youth elite soccer players. Most of the injuries resulted in an absence of fewer than seven days (51.9%).

To our knowledge, this study is the first to examine the injury characteristics of youth non-soccer athletes in Middle East. The main limitations of this study were the inhomogeneous participants' sample of highly trained youth athletes, inaccuracy of records of exposure time duration and the lack of data of organized competition.

CONCLUSION

The rate of overuse and growth-related conditions injuries among youth in multisport in our sports academy is high. Youth athletes have peculiarities; these findings could be cause for concern and merit further studies to establish the risk factors leading to these injuries and to plan strategies of prevention to limit long-term consequences. Disclosure statement No potential conflict of interest was reported by the authors.

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Chapter Three Part One

SPORTS INJURIES ALIGNED TO PREDICTED MATURE HEIGHT IN HIGHLY TRAINED YOUTH ATHLETES: A COHORT STUDY

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ABSTRACT

Objectives: To investigate the association of maturity status with injury incidence in Middle-Eastern youth athletes.

Design: Prospective cohort study.

Setting: Four consecutive seasons (2010–2014), Aspire Academy, Qatar.

Participants: Male athletes (age range: 11–18 years) representing four disciplines enrolled and grouped into two categories: individual sports and racquet sports.

Outcome measures: Injury data collected over four seasons. Athletes' anthropometric characteristics assessed to calculate age at peak height velocity. Predicted mature heights (PMHs) collected and categorized into four quartiles. Athletes had wrist and hand radiographs for assessment of skeletal age (SA). Early and late maturers referred to SA of >1 year older or younger than their chronological age (CA).

Results: For the sample (n=67) across all groups, 43 (64%) athletes had one or more injuries: total of 212 injuries, 4.9 injuries per athlete across study. Survival analysis of maturity status using SA found early maturing athletes had two-fold greater injury risk compared with late maturers (HR 2.04, 95% CI 1.15 to 3.61, p=0.015). PMH associated with injury risk (HR 1.05, 95% CI 1.01 to 1.08, p=0.006).

Athletes in fourth quartile (≥184 cm) had up to two-fold injury risk (HR 2.41, 95% CI 1.42 to 4.08, p=0.001). Racquet and individual sports involved similar injury risk (HR 1.14, 95% CI 0.86 to 1.52, p=0.37).

Conclusion: SA early maturity and PMH gradient were significant predictors of injury in youths.

INTRODUCTION

The range of somatic and biological maturity in individuals of the same chronological age (CA) is large.[1] Such observations are derived from correlational and multivariate studies that compare young individuals of the same age who are at both extremes of the maturity range.[2] Therefore, the assessment of maturity is an important consideration when dealing with adolescent athletes on a longitudinal basis. Further, understanding the cause of disease and injury is vital in predicting and preventing injury.[3]

In young athletes, the demands of their chosen sport are superimposed on normal growth and maturation. A literature review revealed that there is a greater susceptibility to injury during certain periods of growth.[4-6] Indeed, the association between an increased prevalence of injuries and the adolescent growth spurt has long been recognized.[7-9] A recent study analysis[10] on adolescent soccer players revealed greater risk of injury with players within age at peak height velocity (APHV) in comparison with the players before and after APHV. Mismatched rapid growth in the long bones relative to muscular lengthening may disrupt structure, neuromuscular function and physical performance.[11]

Deehan et al.[12] state that an increased participation in sports predisposes the immature skeleton to injury. Furthermore, participation in high intensity sport entails an inherent risk of sports-related injuries, and this is heightened at various stages of growth and maturation.[13] Maturation induces profound changes in the skeletal, neuromuscular and tendinous systems of young athletes[14] and mismatches in biological maturity may create competitive inequality and increase the risk of injury.[15] Le Gall et al.[16] further point out that injury rates generally increase with increasing CA. However, CA is a poor indicator of biological maturity[17]; moreover, Ardern et al.[18] report that CA alone is an unreliable indicator of skeletal maturity. Skeletal age (SA) is generally accepted as the most accurate method of assessing biological maturity,[5,19] by identifying critical periods of development; it also offers a rational method for monitored age-specific training. Before initiating any program for mitigating sports injuries, the magnitude of the problem must be identified and the extent of the injury defined in terms of incidence and severity[20].

A number of studies have been conducted involving injuries in adolescent footballers; conversely, few studies have focused on injuries in non-footballer adolescent athletes in high performance sporting environments.[21] Studies of anthropometric characteristics and biological maturity status as injury risk factors in Middle-Eastern youths are also limited, highlighting the need for more research in this area. Therefore, the purpose of the present study was to investigate injury incidence according to biological maturity using two outcome measures (SA and PHV) in highly trained youth athletes based at a Middle Eastern Sports Academy.

METHODS

Sixty-seven highly trained adolescent athletes (age range 11–18 years) representing athletics and racquet sports (table tennis and squash) from a Middle-Eastern sports school were included in this 4-year study. A prospective, longitudinal cohort design was used and included separate observation periods over four consecutive seasons (2010–2011, 2011–2012, 2012–2013 and 2013–2014), i.e., school years, which lasted from the beginning of September until the end of June (~40 weeks). Participant maturity assessments included both anthropometric measurements, collected three times a season, and SA assessments using Fels method completed once, at the start of every season. Medical screening was performed at the beginning of each season to determine health and injury status. All selected athletes had clearance from a physician to participate in their respective sport. Written informed consent was sought and obtained from parents and assent from all participants. The study was part of a general sports science provision to the sports academy, and all procedures were reviewed and granted by the Institutional Review Board for Human Subjects and conformed to the recommendations of the Declaration of Helsinki.

PARTICIPANTS

Figure 1 shows the flow of participants in the study over consecutive seasons. A total of four sporting disciplines were analyzed, grouped into two categories: athletics and fencing and racquet sports (squash and table tennis). This classification was based on specific sport characteristics and injury risk.[22,23] Inclusion criteria were as follows: (1) the athlete had to be enrolled in the sports school during at least one full school year; (2) athletes with injuries in previous seasons were not excluded from this study, but injuries present at the beginning of the observation period were not included in statistical analyses; and (3) injuries that were not sustained in the context of the sports program (e.g., recreational activities) or data related to sickness or other general medical conditions were not used for further analysis.

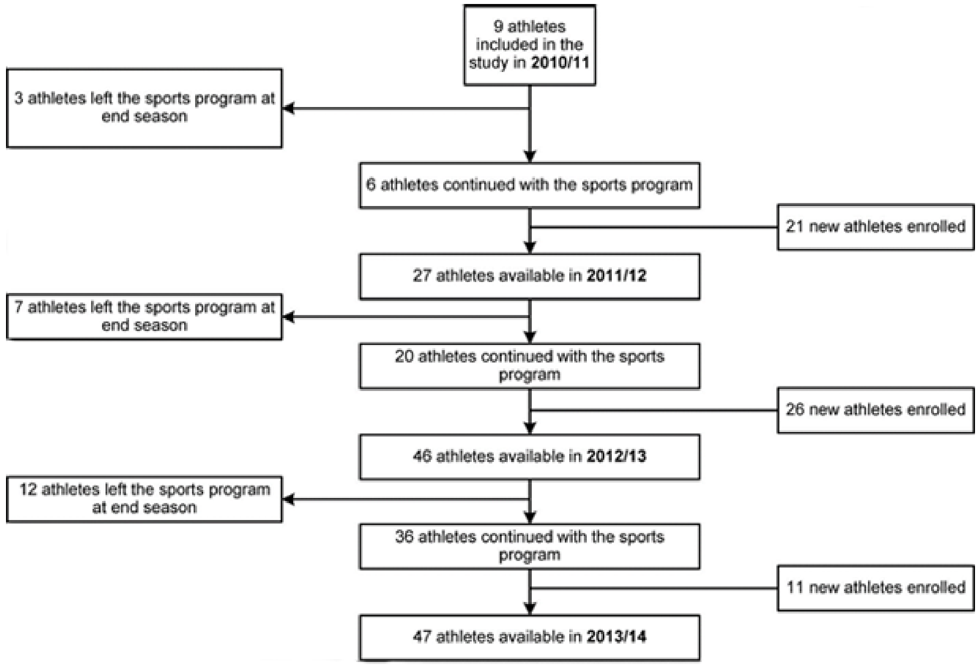

Figure 1: Flowchart describing the inclusion and flow of participants throughout the study.

INJURY DEFINITION AND DATA COLLECTION

An injury was defined as any physical problem, which occurred during sports training, strength and conditioning training or during competition. Injuries were divided into time-loss (TL) injuries and no time-loss (NTL) injuries. A clinical examination and/or treatment of an athlete which did not result in a full training session or competition being missed was described as a problem with NTL injury. A clinical examination and/or treatment of an athlete resulting in a training session or competition being missed the following day (s) was labelled as a TL injury.[23] A traumatic injury was defined as any injury resulting from a specific and identifiable mechanism, including contact and non-contact circumstances with acute onset. Overuse injuries were defined as injuries resulting from insidious onset without a recognizable mechanism. Injury severity was defined, based on days of absence from usual sport participation, as slight (1 day or less), minimal (2–3 days), mild (4–7 days), moderately serious (8–28 days), serious (>28 days up to 6 months) or long-term (>6 months) in accordance with.[24]

All injuries were collected by a physical therapist (AR) with experience of working within youth sport. Data from medical records were used to document all sports related injuries during the study. Each sporting discipline had a dedicated full-time physiotherapist and a full-time employed medical doctor at the sports academy. The medical record used an injury reporting system based upon the football injury reporting system[25] and the Sport Medicine Diagnostic Coding System.[26] Information was gathered concerning all injuries related to sports activity, including several related variables (e.g., type, location, affected structure, mechanism [acute vs overuse], time loss, severity and date of injury).

SOMATIC MATURATION AND ANTHROPOMETRIC MEASUREMENTS

Anthropometric measurements were initially carried out on all participants on a 3-monthly basis along with an estimation of the APHV as a relative indicator of somatic maturity and representing the time of maximum growth in stature during adolescence using Mirwald method[27] for the prediction of growth.[1] APHV was calculated from the first measurement recorded. To ensure that the outcome measures remained consistent and reliable, every effort was made to ensure that measurements were taken at approximately the same time of the season. Measurements were collected by qualified practitioners from the International Society for the Advancement of Kinanthropometry and included stretch stature (±0.1 cm Holtain Limited, Crosswell, UK).

The predicted mature height (PMH) of all participants were collected and categorized into four PMH quartiles (Q1–Q4: Q1 <176 cm; 176 cm ≤Q2 < 180 cm; 180 cm ≤Q3 <184 cm; Q4 ≥184 cm). The athletes were then divided into three maturity groups (late, normal or early maturing) based on the mean ±1.0 year of the APHV of the total sample (late, APHV >mean + 1.0 year; normal, APHV within mean ±1.0 year; early, APHV <mean − 1.0 year). Years from peak height velocity (maturity offset value: CA—maturity offset) was calculated by subtracting the CA at the date of injury from the age at estimated peak height velocity.

SKELETAL MATURATION ASSESSMENT

Each year athletes were required to have a radiograph of the left wrist and hand, a convenient area to examine, and a more accurate method for the assessment of SA,[11] using the Fels method[5,28] which has an advantage over other methods.[29] Maturity status, defined by the difference between CA and SA was calculated and classified into four categories: late, normal, early and mature athletes. Late referred to a SA that was younger than CA by more than 1.0 year, athletes with a normal pattern of maturity had a SA that was within 1.0 year of CA, early referred to a SA that was older than CA by more than 1.0 year and the closure of growth plate determine skeletally mature athletes.

STATISTICAL ANALYSIS

Data were analyzed using Stata 11.0 statistical software. Descriptive statistics were presented as frequencies and proportions (%), and incidence rates were expressed as the number of injuries/numbers of registered athletes. To examine the role of growth status and maturity with the onset of injuries, a univariate Cox regression survival analysis was performed after accounting for repeated visits of athletes over the four seasons. HR with 95% CIs were reported for each factor. Kaplan-Meier curves were plotted for SA groups and time to injury over a season. Where appropriate, 95% CIs are presented. The alpha level of significance was set at 5%.

PATIENT AND PUBLIC INVOLVEMENT STATEMENT

Patients and public were not involved in the analysis of this study.

RESULTS

Throughout the 4-year seasons study period, 67 athletes were enrolled representing 151 athletic seasons. **Table 1** presents the anthropometric characteristics of participants and their maturity status. From these participants, 43 (64%) reported one or more injuries adding up to 212 injuries in total. The injury rate observed per registered athlete amounted to 4.9 injuries over the course of four seasons.

Table 1. Anthropometric characteristics (mean ± SD) of participants according to maturity.

	Late (n=4, 6.0%)	Normal (n=59, 88.1%)	Early (n=4, 6.0%)
CA (years)	13.3 ± 1.3	12.3± 1.0	12.1 ± 0.5
Years From PHV	-2.4 ± 1.2	-1.6 ± 1.1	-0.1 ± 0.9
APHV (years)	15.8 ± 1.5	13.9 ± 0.5	12.2 ± 0.9
PMH (cm)	181.6 ± 5.6	179.4± 4.9	188.4 ± 3.5
%PMH (%)	85.0 ± 3.0	85.0 ± 4.0	90.0 ± 4.0
SA (years)	11.8 ± 0.5	12.8 ± 1.5	12.7 ± 1.8

Abbreviations: APHV, age at peak height velocity; PMH, predicted mature height; SA, skeletal age; SD, standard deviation.

Among all participants (n=67), 4% were classified as late maturers, 33% as normal, 41% as early and 22% as skeletally mature. The overall injury free survival analysis of maturity status using SA assessment indicated that early maturing athletes had a two-fold higher risk of injury over a season compared with late maturing athletes (HR 2.04, 95% CI 1.15 to 3.61, p=0.015), (**figure 2**). There was a trend that early maturing athletes had a greater risk of injury over a season compared with normal athletes (HR 1.62, 95% CI 0.99 to 2.65, p=0.053), but this was only marginally significant. However, injury risk among late and fully mature athletes did not differ from normal maturers.

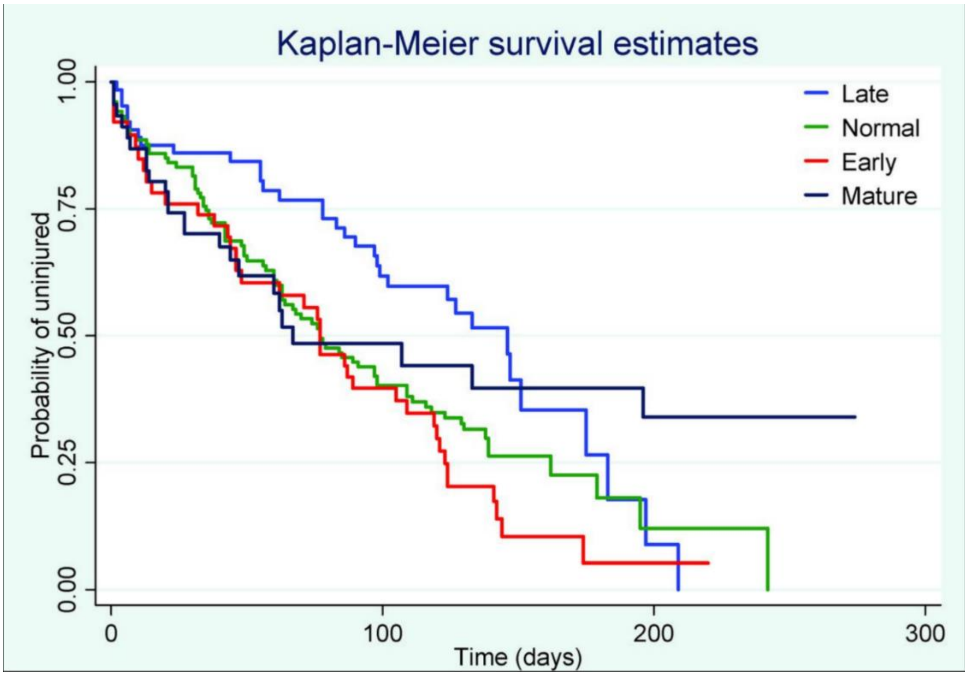

Figure 2: Kaplan-Meier survival analysis of injuries in relation to different skeletal age maturity status.

Somatic maturation and anthropometric measurements: distribution and injury risk

Using anthropometric measurements, among all participants (n=67), 6.0% were classified as late maturing, 85.8% as normal and 6.0% as early. Classification of participant maturity status (late, normal and early) according to age at PHV (APHV) was not significantly associated with overall injury incidence in this cohort of highly trained Middle-Eastern youth athletes. Older PHVs were marginally associated with higher injury risk, but this was not statistically significant (HR 1.11, 95% CI 0.99 to 1.23, p=0.067).

Both PMH (cm) and %PMH were found to be associated with injury risk (HR 1.05, 95% CI 1.01 to 1.08, p=0.006, and HR 1.03, 95% CI 1.00 to 1.06, p=0.026), respectively. When compared with participants in the first quartile for PMH (<176), athletes in the fourth quartile (≥184 cm) had a two and half times greater risk of injury (HR 2.41, 95% CI 1.42 to 4.08, p=0.001) over a season.

No significant differences were observed in the injury risk between racquet sports (n=30) and individual sports athletes (n=37; HR 1.14, 95% CI, 0.86 to 1.52, p=0.37).

DISCUSSION

The present investigation was carried out to examine injury incidence according to maturity status. Biological maturity status and height gradient play a significant role in injury risk profiles of highly trained youth athletes. The results of the current study show that athletes maturing at a younger age are at significantly greater risk of injury, more than two-fold, compared with their later maturing counterparts. Taller athletes were also found to be significantly more at risk of injury.

There is limited and contrasting evidence on the relationship between maturity and injury in youth sports.[10,30,31] In this study, SA maturity (Fels method) showed that early maturing athletes had twice the risk of injury over a season compared with late maturing athletes. This finding is consistent with previous study,[5] that described that early maturing athletes are significantly more at risk of injury than late or normally maturing athletes. A possible explanation could be that youth players with higher engagement and performance advantages are often associated with early maturation, usually transient during adolescence, and maybe reversed in early adulthood.[16]

However, our study results were inconsistent with other study[30] on youth athletes, in which late maturing athletes have a higher injury rate compared with their earlier maturing counterparts. A plausible explanation could be that Fourchet et al.[30] examined anthropometric data collected from a track and field cohort for their findings, while our study resulted from maturity status derived from bone age but with no substantial association from APHV.

In the present study, no significant association was observed between APHV and injury risk (HR 0.90, 95% CI 0.74 to 1.11, p=0.329), which is inconsistent with recent data on youth alpine ski racing[32] and other studies on talented Dutch and English youth soccer players[5,33] which show a heightened period of risk around the time of peak height velocity. An explanation of these discrepancies could be that our study cohort was not large enough, as the APHV method appears to be useful in youth talent selection and injury prevention programs because it can be easily applied in a large cohort of young athletes.[34]

PMH and %PMH at a given age are minimally invasive, feasibly practical indicators of somatic maturation,[17,35] especially if mature height can be assessed without an estimate of SA.[28] In this study, the PMH and %PMH revealed that both indicators were associated with injury risk (HR 1.05, 95% CI 1.01 to 1.08, p=0.006), and HR 1.03, 95% CI 1.00 to 1.06, p=0.026), respectively. When compared with participants in the first quartile for PMH

(<176), athletes in the fourth quartile (≥184 cm) had two and a half times greater risk of injury (HR 2.41, 95% CI 1.42 to 4.08, p=0.001). The present results are partly in line with previous studies on other sports. Johnson et al.[5] showed that gains in height in youth footballers over a season were associated with an increased number of injuries. The study of Kemper et al.[36] on elite youth soccer players with growth rates of at least 0.6 cm/month showed a higher risk for injury. In a different study on soccer athletes, it was found that the tallest boys had the highest incidence of injury.[37] However, these findings and those of the present study are not in line with a study on youth football players,[38] in which injured and non-injured players did not differ in percentage of mature height. An explanation could be that the definition of reportable injury in the methods of the study, which considered only time loss injuries, did not capture the full spectrum of injuries and therefore overlooked other injuries with insidious onset e.g., growth conditions.

The results of this study have some important practical implications. Malina et al.[2] advocate the documentation of anthropometric characteristics, biological maturity and physical fitness parameters as crucial aids in the prevention of injury. Non-invasive methods for estimating maturity status may allow youth programs to match players using maturity status rather than CA, and thus equalize competition to some extent. An unequal competition is regarded as an impediment to personal development.[39] Furthermore, it has been suggested that there is an overwhelming bias in sport favouring taller athletes,[40] and data on Olympic medal winners show that many running and jumping events are seriously biased in favour of the very tall.[41]

When examining the classification resulting from SA of late (4%), normal (33%), early (41%) and skeletally mature athletes (22%), the under-representation of late and preponderance of early maturing athletes in this cohort is consistent with observations for male youth athletes in several sports including soccer and alpine ski racing.[10,19,32] However, these results and those of the present study are not in line with the study of Johnson et al.[5] on schoolboy footballers, in which two thirds of their players fall within the normal maturity category. Moreover, Le Gall et al.[16] classify only 12.0% as late maturers, 63.5% as normal maturers, and 24.5% as early maturers. These discrepancies are believed to be due to differences in selection policies and talent identification policies (physical, technical and tactical skills) of varying elite development centers. Several studies point out that athletes who are more advanced in their biological maturity perform better than their later maturing peers and have a better chance of being selected.[42-44] Youth sport is highly selective, with a maturity-associated selection/exclusion process.[35]

IMPLICATIONS AND CONCEPTS FOR PREVENTION

The findings in this study have several implications for youth athletes. First, our data suggest that adolescent athletes might be identified and selected with a preference for youths with advanced maturity. Such selection strategies which favour early maturers entail significant risks of injury. Accordingly, those involved in the selection and development of young athletes should be cognizant of temporary changes in motor control that may occur during these periods,[45] consider maturity status, develop appropriate training programs to optimize training adaptation, design injury prevention plans to minimize activity related injury risk and mitigate long term youth injury consequences.

Limitations of the current study should be noted. First, biological maturation methods have inherent limitations when applied to youth athletes and need to be applied with caution. Although SA is a gold standard indicator of maturation, it has major limitations in expense and minimal radiation and lack of knowledgeable staff for assessment protocols and the interpretation of results.[46] Although our sample size is small, we have a follow-up over four seasons. Another limitation, we had no data on training or competition exposure, which reduces the comparability with other studies reporting injury incidence.

It must also be remembered that, except for accidents, a sports injury can rarely be ascribed to a single factor, but rather to an association of causes or circumstances and the interaction among a web of determinants.[47,48]

CONCLUSIONS

The findings of the present study showed that maturity status plus PMH and %PMH are associated with injury in individual and racquet sports but no association has been established between APHV and injury. As SA varies individually in rate and timing, and mismatches in maturity may create competitive inequality and increase injury incidence, it is suggested that biological maturity should be considered during training to help prevent injury. Given the peculiarity of youth athletes it is important to optimize the planning of training activities to further improve the understanding of the link between training, growth and injury.

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Chapter Three Part Two

LATE MATURITY LEVEL ASSOCIATED WITH A TRIPLING OF GROWTH-RELATED INJURY RISK IN HIGHLY TRAINED MIDDLE-EASTERN YOUTH ATHLETES: A COHORT STUDY

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ABSTRACT

Objectives: To investigate the association of various stages of maturity level with sports-related injury characteristics in Middle-Eastern youth athletes.

Design: Prospective cohort study.

Setting: Four consecutive seasons (2010–2014), Aspire Academy, Qatar.

Participants: A total of 67 highly trained athletes from youth sports academy were observed for 4 consecutive seasons.

Outcome: Injuries, peak height velocity (PHV) age, predicted mature heights, chronological age and injury incidence per registered player.

Results: Among all participants (n=67), 6.0% were classified as late mature (LM), 88% as normal mature (NM) and 6.0% as early mature (EM). The mean age at PHV was 15.8±1.5 for LM, 13.9±0.5 for NM and 12.2±0.9 for EM.

From 67 included athletes, there were a total of 211 injuries, 43 (64%) had one or more injuries: with incidence rate of 4.9 injuries per athlete. Compared with the NM (incidence 0.6, 95% [0.4 to 0.8]), LM athletes (incidence 2.0, 95% [0.9 to 3.9]) presented with a significantly higher (p= 0.008) osteochondroses injury rate. Also, EM athletes (incidence 1.5, 95% [0.6 to 3.3]), presented with significantly higher (p=0.018) hematoma/contusion/bruise injury type compared to their NM (incidence 0.4, 95% [0.3 to 0.6]) peers. There were no differences between maturity groups when patterns of injury mechanism and severity were analyzed.

Conclusions: Among highly trained young athletes, late mature from youth academy-based setting were more prone to growth-related overuse injuries. Based on higher injury incidence, we suggest that research on injury risk factors and preventive measures should primarily target late mature age groups. Additional intervention should be based on bio-banding rather than conventional reference to chronological age.

Keywords: Youth athlete; peak height velocity; age group; chronological age; biological age; injury incidence

Strengths and limitations of this study: The investigation aimed to develop an understanding of biological age relevance, injury type and growth-related conditions

Athletes should be allocated to pre- PHV, circum and post- PHV groups to identify differences in traumatic and overuse injury incidence.

The diverse sample sizes based on the group classification and the three maturity groups must be considered a limitation of the study because direct comparisons are difficult.

INTRODUCTION

There has been an increased interest in the development of youth team and individual sports,[1] which led to a growing involvement of adolescents in sports and gave rise to concerns regarding the risk of sports injuries.[2] Although evidence suggests that sports participation is beneficial from a public health perspective, injuries are significant negative side effects over both the short and long term[3] and can counter the beneficial aspects related to activities, especially if an athlete is unable to continue to participate as a consequence of long-term injury. High volume and intensity of training expose young athletes to increased risk of injury.[2,4]

Growth injuries are unique to young athletes as a result of increased involvement in professional sports activities by children and adolescents.[5] In young athletes, demands of sports are superimposed on normal growth and maturation.[6] Maturation status has been reported to influence injury rate in several sports, but the relationship between maturation and injury incidence probably varies among sports.[7] Risk of sports-related injury is heightened at various stages of growth and maturation.[8]

However, only few studies described injuries at the junior level despite the potential impact of maturation status on career pathways and long-term health.[9]

According to van Mechelen et al.[10] sports injury prevention should start with epidemiology, injury surveillance being the basis of prevention. It describes injury characteristics, provides information on risk factors and helps define prevention strategies.[4] A range of studies highlighted sports-related injury characteristics in youth team sports. However, there is a paucity of information pertaining to youth athletes in individual or racket sports.

Our main hypothesis was that injury risk, type and severity would be different according to biological maturity level. Furthermore, we hypothesized that different injury mechanism (acute or overuse) relate to different categories of maturity status.

The purposes of this study were to describe the type and severity of injuries sustained by young Middle- Eastern highly trained athletes and to investigate the influence of maturation on injury occurrence.

METHODS

Sixty-seven highly trained adolescent athletes (age range 11–18 y) representing athletics (n=37) and racquet sports (table tennis and squash, n=30) from a Middle-Eastern sports school were included in this four-year study as described previously.[11] In brief, a prospective, longitudinal cohort design was used and included separate observation periods over four consecutive seasons (20010–2011, 2011–2012, 2012–2013, and 2013–2014), i.e., school years, which lasted from the beginning of September until the end of June (~40 weeks). Participant maturity assessments and anthropometric measurements were conducted at the start of every season and repeated every three months. Medical screening was performed at the beginning of each season to determine health and injury status. All selected athletes had clearance from a physician to participate in their respective sport. Written informed consent was sought and obtained from parents and assent from all participants. The study was part of a general sports science provision to the sports academy, and all procedures were reviewed and granted by the Institutional Review Board (IRB) for Human Subjects and conformed to the recommendations of the Declaration of Helsinki.

Inclusion criteria were as follows: (1) the athlete had to be enrolled in the sports school during at least one full school year; (2) athletes with injuries in previous seasons were not excluded from this study, but injuries present at the beginning of the observation period were not included in statistical analyses; and (3) injuries that were not sustained in the context of the sports program or data related to sickness or other general medical conditions were not used for further analysis.

Injury data collection

All injuries were assessed by a physical therapist (AR) with experience of working within youth sport. Data from medical records were used to document all sports related injuries during the study. Each sporting discipline had a dedicated full-time physiotherapist and a full-time employed medical doctor at the sports academy. The medical record used an injury reporting system based upon the football injury reporting system[12] and the Sport Medicine Diagnostic Coding System.[13] Information was gathered concerning all injuries related to sports activity, including several related variables (e.g. type, location, affected structure, mechanism [acute vs. overuse], time loss, severity, and date of injury).

Somatic maturation and anthropometric measurements

Anthropometric measurements were initially carried out on all participants along with an estimation of the age at peak height velocity (APHV) as a relative indicator of somatic maturity and representing the time of maximum growth in stature during adolescence.[14]

To ensure that the outcome measures remained consistent and reliable, every effort was made to ensure that measurements were taken at approximately the same time of the season. Measurements were collected by qualified practitioners from the International Society for the Advancement of Kinanthropometry (ISAK) and included stretch stature (± 0.1 cm Holtain Limited, Crosswell, UK).

The athletes were divided into three maturity groups: Late mature (LM), normal mature (NM), and early mature (EM) based on the mean ± 1.0 year of the APHV of the total sample (late, APHV > mean + 1.0 y; normal, APHV within mean ± 1.0 y; early, APHV < mean – 1.0 y).

Years from peak height velocity was calculated by subtracting the chronological age at the date of injury from estimated peak height velocity age.

Definition of Injury

Injuries were recorded as a physical complaint requiring the attention of medical staff, which occurred during sports training, strength and conditioning training or during competition. Injuries were divided into time-loss (TL) injuries and no time-loss (NTL) injuries. A clinical examination and/or treatment of an athlete which did not result in a full training session or competition being missed was described as a "medical attention" with NTL injury. A clinical examination and/or treatment of an athlete resulting in a training session or competition being missed the following day(s) was labelled as a TL injury.[12] A traumatic injury was defined as any injury resulting from a specific and identifiable mechanism, including contact and non-contact circumstances with acute onset. Overuse injuries were defined as injuries resulting from insidious onset without a recognisable mechanism. Injury severity was defined, based on days of absence from usual sport participation, mild injuries with absence below 7 days, moderate injuries causing a median absence of 8–28 days and severe injuries causing a median absence of more than 28 days adapted from Ekstrand et al.[15]

Statistical Analysis

Data were analysed using statistical software (Stata Corporation, College Station, Texas). Descriptive statistics were presented as frequencies and proportions (%), and incidence rates were expressed as the number of injuries/numbers of registered athletes with 95% Confidence intervals. Poisson 95% confidence intervals were calculated for the incidence rates and difference between incidence rates was calculated using techniques described by Frome and Checkoway[16] . The alpha level of significance was set at 5%.

Patient and public involvement statement

Patients and public were not involved in the analysis of this study.

RESULTS

In this study, 67 athletes were enrolled representing 151 athletic seasons. From these participants, 43 (64%) reported one or more injuries adding up to 211 injuries in total. Classification of participant maturity status (late, normal and early) according to age at PHV (APHV) was not significantly associated with overall injury incidence in this cohort. Among all participants, 6.0% were classified as LM, 88% as NM and 6.0% as EM. The mean chronological age (CA) of LM was 13.3±1.1, NM 12.3±1.0 and EM 12.1±0.5. **Figure 1.** Compares the injury incidence of various injuries by maturity level.

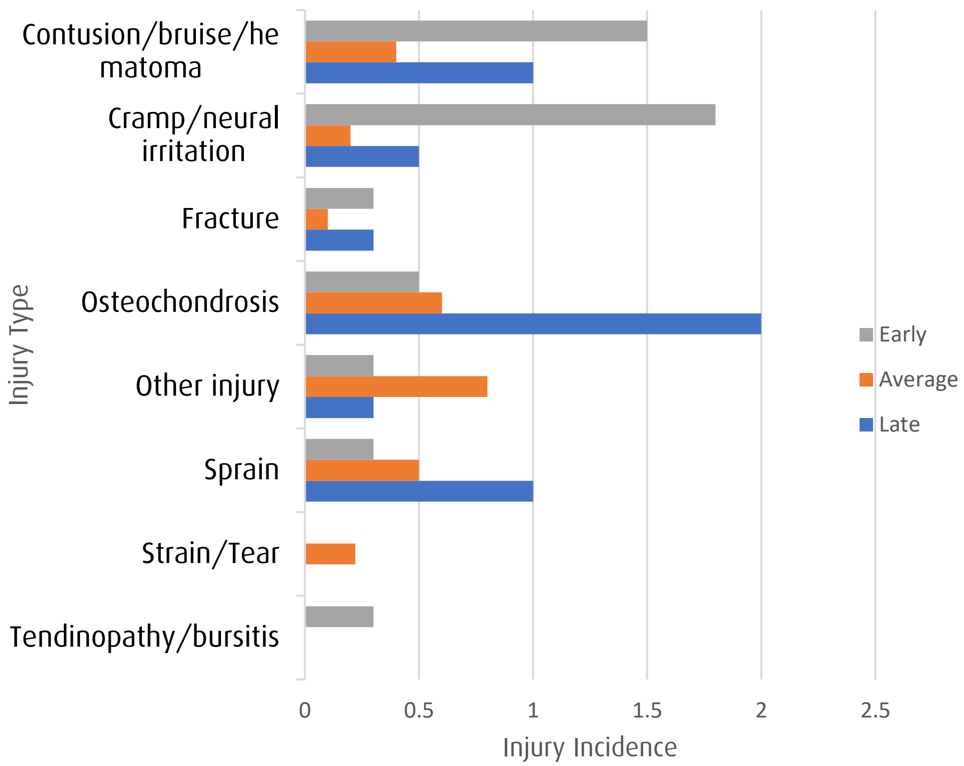

Figure 1: Injury incidence of various injuries by maturity level

Table 1: Maturity level and injury characteristics

Injury characteristic		N[a]	Inc[b]/(95%CI[c])	Mean± SD[d]	Severity of injury (days lost)		
					Minor (0-7)	*Moderate (7-28)*	*Severe (>28)*
Late mature *(n=4)*							
Injury type	*Contusion*	*4*	*1.0 (0.3 to 2.6)*	*18.5±17.5*	*1*	*2*	*1*
	Cramp/neural irritation	*2*	*0.5 (0.1 to 1.8)*	*2.0±1.4*	*2*	*0*	*0*
	Fracture	*1*	*0.3 (0.0 to 1.4)*	*30.0*	*0*	*0*	*1*
	Osteochondrosis	*8*	*2.0 (0.9 to 3.9)*	*7.5±5.7*	*5*	*0*	*0*
	Sprain	*4*	*1.0 (0.3 to 2.6)*	*16.3±12.9*	*1*	*2*	*1*
	Strain/tear	*0*	*0*	*0*	*0*	*0*	*0*
	Tendinopathy/bursitis	*0*	*0*	*0*	*0*	*0*	*0*
	Other injury	*1*	*0.3 (0.0 to 1.4)*	*8.0*	*0*	*1*	*0*
Injury mechanism	*Overuse (insidious onset)*	*10*	*2.5 (1.2 to 4.6)*	*6.9±5.4*	*6*	*4*	*0*
	Acute (sudden onset)	*10*	*2.5 (1.2 to 4.6)*	*17.2±14.3*	*3*	*4*	*3*
Normal Mature *(n=59)*							
Injury type	*Contusion*	*26*	*0.4 (0.3 to 0.6)*	*6±13*	*22*	*2*	*2*
	Cramp/neural irritation	*11*	*0.2 (0.1 to 0.3)*	*4.2±5.2*	*7*	*4*	*0*
	Fracture	*7*	*0.1 (0.0 to 0.2)*	*28.6±24.2*	*2*	*2*	*3*
	Osteochondrosis	*36*	*0.6 (0.4 to 0.8)*	*13.2±16.4*	*11*	*19*	*5*
	Sprain	*27*	*0.5 (0.3 to 0.7)*	*6.9±8.8*	*17*	*7*	*2*
	Strain/tear	*14*	*0.2 (0.1 to 0.4)*	*22.1±14.7*	*2*	*8*	*3*
	Tendinopathy/bursitis	*2*	*0 (0.0 to 0.1)*	*1.5±2.1*	*2*	*0*	*0*
	Other injury	*49*	*0.8 (0.6 to 1.1)*	*8.9±16.2*	*37*	*7*	*0*
Injury mechanism	*Overuse (insidious onset)*	*75*	*1.3 (1.0 to 1.6)*	*9±10.3*	*40*	*26*	*8*
	Acute (sudden onset)	*98*	*1.7 (1.3 to 2.0)*	*15.8±45*	*60*	*23*	*13*
Early mature *(n=4)*							
Injury type	*Contusion*	*6*	*1.5 (0.6 to 3.3)*	*1.8±2.0*	*6*	*0*	*0*
	Cramp/neural irritation	*7*	*1.8 (0.7 to 3.6)*	*5.0±4.1*	*3*	*4*	*0*
	Fracture	*1*	*0.3 (0.0 to 1.4)*	*28*	*0*	*1*	*0*
	Osteochondrosis	*2*	*0.5 (0.1 to 1.8)*	*24.5±21.9*	*0*	*1*	*0*
	Sprain	*1*	*0.3 (0.0 to 1.4)*	*21*	*0*	*1*	*0*
	Strain/tear	*0*	*0*	*0*	*0*	*0*	*0*
	Tendinopathy/bursitis	*1*	*0.3 (0.0 to 1.4)*	*11*	*0*	*1*	*0*
	Other injury	*1*	*0.3 (0.0 to 1.4)*	*2*	*1*	*0*	*0*
Injury mechanism	*Overuse (insidious onset)*	*9*	*2.3 (1.0 to 4.3)*	*10.3±11.8*	*2*	*6*	*1*
	Acute (sudden onset)	*10*	*2.5 (1.2 to 4.6)*	*6.4±9.8*	*8*	*2*	*0*

Legend: [a], *number;* [b], *incidence;* [c], *confidence interval;* [d] *severity of injury means days and standard deviation*

Compared with the NM (incidence 0.6, 95% [0.4 to 0.8]), LM athletes (incidence 2.0, 95% [0.9 to 3.9]) presented with a significantly higher (p= 0.008) osteochondroses injury rate. Also, EM athletes (incidence 1.5, 95% [0.6 to 3.3]), presented with significantly higher (p=0.018) hematoma/contusion/bruise injury type compared to their NM (incidence 0.4, 95% [0.3 to 0.6]) peers.

Table 1 shows the injury incidence per player and injury severity according to injury type and mechanism in the LM, NM and EM groups.
There were no differences between maturity groups when pattern of injury mechanism and severity were analyzed.

DISCUSSION

The present investigation was carried out to examine sports-related injuries incidence of youth athletes and their characteristics according to maturity status. Biological maturity status plays a significant role in injury risk and type in highly trained youth athletes. The results of the current study show that athletes maturing at an older age are highly significantly at greater risk of growth-related overuse injuries type, more than three-fold, compared with their normal maturing counterparts. In contrast, athletes maturing at younger age were found to be significantly more at risk of hematoma/contusion/bruise injury type compared to their normal mature peers.
Our study finding about the high incidence rate (2.0, 95% [0.9 to 3.9], p=0.008) of osteochondroses among LM athletes are well in-line with those reported in the literature by Fourchet et al.[7] study on adolescent track and field athletes.
Our study results corroborated also with Silván et al.[17] findings on adolescent track and field athletes from different athletic disciplines where apophysitis was the most common overuse injury, being significantly associated to LM status (injury incidence 4.1, p<0.01).
Our study results are in-line with the findings of van der Sluis et al.[6] on a group of soccer players maturing at an older age, and overuse injury incidence in the year before PHV is 7 times higher than the earlier maturing group. Our findings are in-line with recent trends that have highlighted LM status as risk factor for overuse injury in both team[1,18,19] and individual sports.[7,17]
In respect of an academy environment, youth athletes are transitioning too rapidly to higher levels of training and competition demands during adolescence[20]. Therefore, such type of injuries probably relates to an inadequate adaptation to the physical demands imposed by training. Also, with an increase in a child’s age, there is greater exposure to training and competition, which involves high levels of repetitive loading which can increase injury risk.
It is well known that growth-related factors such as biological immaturity contribute to overuse injuries.[2,21] The risk of sustaining such an overuse injury is strongly intensified

during the adolescent growth spurt.[22] Additionally, studies of soccer players revealed that late maturing athletes were at a higher risk for overuse injuries[18] or severe traumatic injuries.[19]

Sites of vigorous musculoskeletal development in long bones and their musculotendinous attachments are the specific areas of potential sports injury.[23] The physis, as the weakest part of the bone, is a site highly prone to injury in youth athletes. Osteochondroses, a group of disorders ''bone-cartilage conditions,'' are a heterogeneous group of injuries to the epiphyses, physis, and apophyses of children.[5] Irritation at the attachment site and protuberance is called apophysitis.[5] Apophysitis are a subset of osteochondroses occurring at the bony attachment sites of musculotendinous units.

In the present study, EM athletes presented with significantly higher ($p=0.018$) hematoma/contusion/bruise injury type compared to their NM peers. Backous et al.[24] explained that more aggressive play and greater risk taking associated with maturity may be reflected by the high incidence of contusion injuries in the clearly mature soccer players. Rumpf et al.[25] reported that injuries increase steadily with age but definitely after the age of 14, which coincides with PHV.

Periods around PHV have been associated with an increased injury risk, A decrease in flexibility and bone density during the growth spurt may result in increased vulnerability of the skeletal system.[26] Previous research has shown that relative increase of training volume is one of the most important predictors of injuries.[27,28] Therefore, the quantification of training load, variations during the year and the risk of injuries should also be investigated based on a daily monitoring system.

Previous studies[11,29] showed that youth sport is highly selective with a maturity-associated selection/exclusion process, as athletes who are more advanced in their biological maturity perform better than their later maturing peers and have a better chance of being selected.[30,31] Hence LM athletes are target of compound hindrance due biased selection process and eminent vulnerability to growth-related injuries and its subsequences.

Implications and concepts for prevention

The findings in this study have several implications for youth athletes. First, our data suggest that LM adolescent athletes are prone to osteochondroses injury type. However, there is a paucity of information in the medical literature pertaining to the management of injuries of youth athletes. Those involved with youth sports should be cognizant of the impact of growth and maturation on immature skeleton and derive an adapted clinical framework to adequately manage and prevent growth-related injuries. Second, we suggest that maturity status and not only chronological age should be considered to advance training plan incorporated into the long-term athlete development scheme. Training load should be structured in such a way that maturity is taken into account, athletic development is maximized and the chance of injuries is minimized.[18]

Limitations of the current study should be noted. The diverse sample sizes based on the group classification and the three maturity groups must be considered a limitation of the study because direct comparisons are difficult. Furthermore, the rates of injuries were relatively low during the study period in some sub-categories to yield conclusive results. Further investigations with larger sample sizes and a longer observation period are recommended to detect risk factors between groups.

CONCLUSIONS

In youth academy setting, late mature athletes were more prone to osteochondrosis, growth-related injuries. We suggest that individual growth and maturation should be monitored as part of screening approach to identify and target those at-risk sub-group through adapted prevention plans.

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Chapter Four

BEIGHTON SCORING OF JOINT LAXITY AND INJURY INCIDENCE IN MIDDLE EASTERN MALE YOUTH ATHLETES: COHORT STUDY

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ABSTRACT

Objectives: To examine the association between generalized joint laxity (GJL) and injury rates in Middle Eastern male youth athletes.

Design: Prospective observational study consisting of GJL screen and injury audit (season 2009/2010).

Setting: Aspire Sports Academy Doha, Qatar.

Participants: A total of 226 adolescent male athletes (mean age: 14.2 years; SD: 1.7; range: 10–18) involved in 15 sporting activities were grouped into contact and non-contact sports. All available athletes were included in this study.

Outcome measures: A seasonal injury audit, athletes' anthropometric characteristics, for example, weight, height and body mass index and screen for GJL to determine Beighton Score (BS).

Results: The 226 athletes sustained 596 injuries and 75% reported at least one injury over a seasonal injury audit. Players in contact sports were injured more often than players in non-contact sports (more frequent injuries than injury-free time in contact sports; 127 days (95% CI 93 to 160) vs 176 days in non-contact sports (95% CI 118 to 234) ($p<0.001$). Survival analysis showed that gradient BS was not associated with injury HR=1.004 (95% CI 0.95 to 1.06) in the overall cohort. However, BS was associated with a greater injury risk in contact sports (HR: 1.29; 95% CI 1.05 to 1.59; $p=0.015$).

Conclusion: Greater GJL, defined by gradient BS, plus involvement in contact sports together influence injury risk in youth athletes. Preseason documentation of GJL scoring should be considered specifically for contact sports as injury pre-emptive measure.

INTRODUCTION

Clinicians have variably described both a lack of generalized flexibility ('stiffness') and an increase in generalized joint laxity (GJL) ('hyperlaxity') as being intrinsic risk factors for injury.[1] It is unusual, however, for a clinician to be able to ascribe an exact definition of such increased or decreased flexibility, and particularly at what point this variation from normal becomes pathognomonic. A better understanding of this relation would facilitate the development of an injury profile index to assist in directing athletes into sports where their individual traits are protective and beneficial, rather than detrimental.[2] Typically, in clinical practice, GJL is quantified through use of the Beighton classification system comprising scoring of nine individual tests of movement on a dichotomous (1=yes, 0=no) score for a maximum of nine points (i.e., Beighton Score (BS)).[3,4] Previous work[5] has suggested the usefulness of defining a clinical cut-off point of 4/9 instead of considering the score to be linearly related to injury risk; however, this definition remains debated.[6]

Clinicians and coaches have described GJL to be either beneficial or disadvantageous to sporting performance and injury risk according to the sport being examined. For instance, it is unusual for any athlete to reach international standards in female gymnastics without being defined as hypermobile in the Beighton Classification.[7] Conversely, some authors argue that GJL was a predisposing factor to injuries,[8,9] and subjects with such GJL should therefore be recommended against participation in sports that involve heavy physical contact or the risk of falls which might likely lead to injury. While the data is scarce, some research suggests hyperlaxity as a risk factor for injury in adolescents and others.[10] There is a paucity of high-quality reports to backup these widely held beliefs as reported in a recent systematic review and meta-analysis showing GJL to increase the odds of knee but not ankle injury, and no data on injury to the foot, hip, spine or upper limb.[1] Further, this review concluded that there was insufficient data to examine the interaction of sporting participation (e.g., contact vs non-contact sports).[1]

The prevalence of GJL varies with gender and ethnicity.[3,7,11] To gather useful information regarding the post-test odds of any potential risk factor's interaction with GJL, it is critical to document the pretest incidence, that is the prevalence of GJL in the population of interest.[12,13]

Current understanding of the prevalence and descriptive epidemiology of GJL in childhood is limited, making it difficult to draw clear conclusions about causal pathways. Also the extent to which GJL is associated with injury is unclear.[14]

Therefore, the aim of this study was to evaluate the relationships between GJL (BS) on the risk of injury among youth athletes engaged in different sports activities.

METHODS

Study design and settings

Prospective cohort study design at the Aspire Academy of Sports, Doha, State of Qatar. Study took place during the 2009/2010 academic season with a follow-up period of 9 months.

Participants

Participants were full-time registered adolescent athletes at Aspire Academy for Sports, Doha, State of Qatar. Athletes included in the study were all male, aged 10–18 years (average age 14.2±1.7 years) and screened for GJL.
All 226 participants met the inclusion criteria and were involved in 15 different sport activities: football (n=125), track and field (n=35), fencing (n=8), gymnastics (n=6), swimming and diving (n=6), table tennis (n=6), tennis (n=7), Tae kwon do (n=2), judo (n=5), squash (n=10), shooting (n=4), golf (n=5), rowing (n=2), multi (n=1) and sailing (n=2). The sport disciplines were grouped into two categories: contact (n=132) and non-contact sports (n=94).
Parental consent and child's assent were obtained for all measurements.

Injury definition and data collection

An injury was defined as a physical complaint, which occurred during sports training, strength and conditioning training or during competition. A traumatic injury was defined as an injury resulting from a specific and identifiable mechanism, including contact and non-contact circumstances with acute onset. Overuse injuries were defined as injuries resulting from insidious onset without a recognizable mechanism.[15]
All injuries were collected by two physical therapists. Data from medical records were used to document all sports-related injuries during the study. Each sporting discipline had a dedicated full-time physiotherapist and a full-time employed medical doctor at the sports academy. The medical record used an injury reporting system based on the football injury reporting system[16] and the Sport Medicine Diagnostic Coding System.[17] Information

was gathered concerning all injuries related to sports activity, including several related variables (e.g., type, location, affected structure, mechanism (acute vs overuse)) by clinician. Injury severity was defined, based on days of absence from usual sport participation, as slight (1 day or less), minimal (2–3 days), mild (4–7 days), moderately serious (8–28 days), serious (>28 days up to 6 months) or long-term (>6 months).[18]

Measurement of GJL

GJL was assessed by two trained measurers or physiotherapists (AR and JH). We used 20 cm and 30 cm goniometers. Reporting of the joint range at the thumbs, fifth fingers, knees, elbows and spine were after the methods initially described by Beighton and Horan.[3,19] The tests were done with the athletes standing, except for the knee extension test measured with the subject supine. All tests were performed bilaterally, except for trunk flexion. Each positive test marked 1 point for a total score of 0–9. The BS was recorded first as an absolute score, and later analyzed in the clinical classifications of cut-offs: 0–2, 3–5 and >5[5]; 0–4 and >4; 0, 1–5 and ≥6.

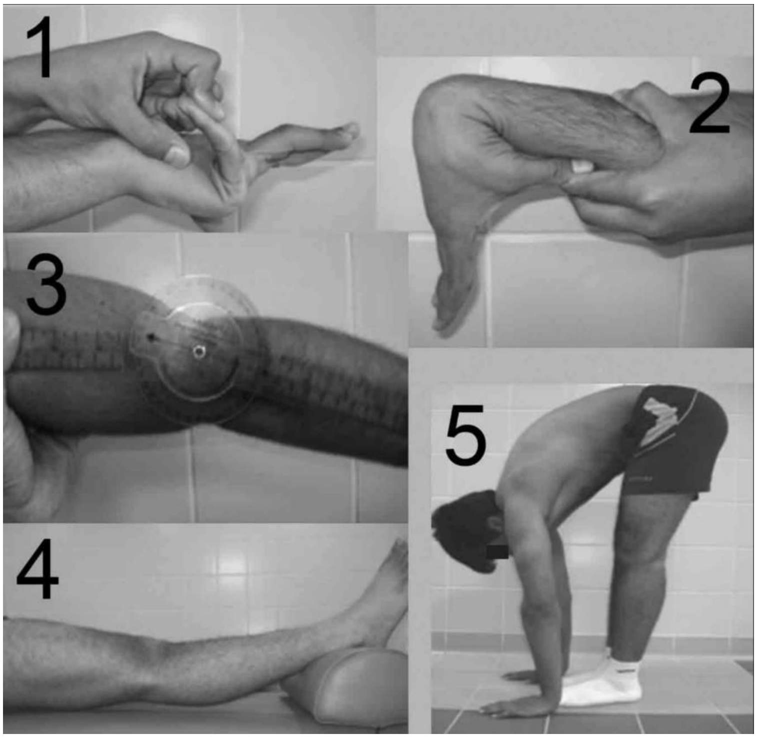

Figure 1: Beighton Scoring system. (1) Little finger passive dorsiflexion beyond 90°. (2) Thumb passive dorsiflexion to the flexor aspect of the forearm. (3) Elbow hyperextension beyond 10°. (4) Knee hyperextension beyond 10°. (5) Palms and hands can rest flat on the floor.

Anthropometric measures

At the sports science unit of the academy, height was measured to the last complete millimetre, using a Harpenden stadiometer. Weight was measured to the nearest 50 gm using a body fat analyser (model TBF 305; Tanita). Body mass index (BMI) was calculated as kg/m^2 and subjects were categorized as underweight (BMI 18.5), ideal weight (BMI 18.5–24.9), overweight (BMI 25–29.9) or obese (BMI ≥30) based on standard definitions.

Statistical analysis

Statistical analyses were performed with the use of SPSS V.19.0. The Student's t-test was used to compare mean values of normally distributed data (age, height, weight and BMI). $\chi 2$ test was used to compare categorical variables in non-injured athletes versus athletes injured at least once. Data were analyzed comparing Kaplan-Meier survival estimates by using the Breslow statistic. Curves were compared with the Breslow statistic based on dependent factor BS group stratified by sports category (contact and non-contact) to determine if GJL was associated with injury incidence, thus adjusting sports category as potential effect modifier. Median injury-free survival time and 95% CI were calculated. For the above analysis, only first injury per player was counted. In addition, subsequent survival analyses were carried out in STATA V.11.0. A stratified Cox proportional hazard model that stratifies order of recurrent injuries after adjusting the variances of HRs among recurrent events on the same subjects was performed using marginal Prentice, Williams and Peterson counting process method[20] to further explore the temporal effect of GJL on recurrent events. HRs and 95% CI were calculated. As the incidence of GJL was unknown in Middle Eastern Arabic populations, the assumption was made that the incidence was similar to Caucasians, and thus a preliminary power analysis suggests that to detect an effect of GJL on injury at p=0.05, approximately 200 subjects would be required (for an effect size of 0.1). P value ≤ 0.05 was used to define statistical significance.

Patient and public involvement statement

Patients and public were not involved in the analysis of this study.

RESULTS

In this cohort (N=226), contact sports (football, judo and tae kwon do) represented 58% (n=132) and non-contact sports (track and field and other sports) represented 42% (n=94). The prevalence of GJL, as defined using a BS cut-off of ≥6 was only 3.1% and the subgroup of 1–5 was 48.2%. Figure 2 shows the distribution of GJL across all study groups.

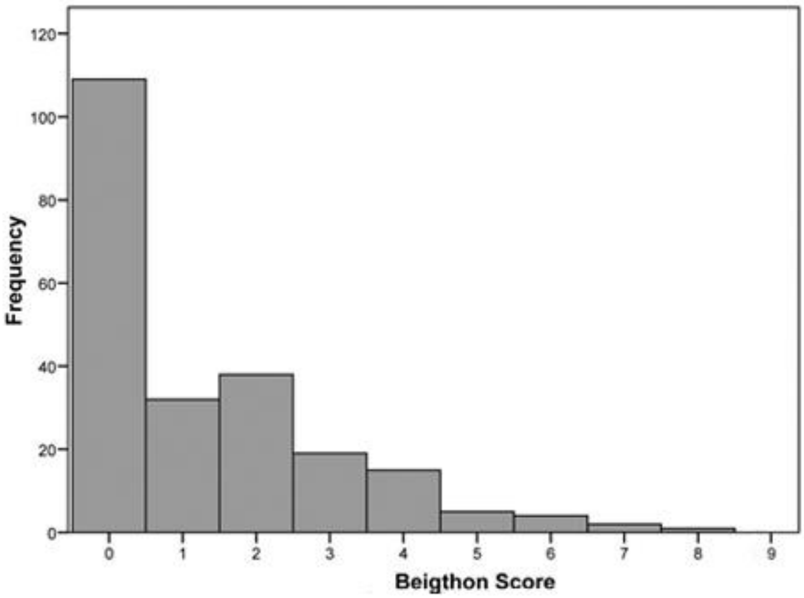

Figure 2: Frequency histogram for the entire cohort of student athletes classified by Beighton Score.

Out of the 226 athletes, a total of 596 injuries were identified and 74.8% reported with at least one injury over a seasonal injury audit. **Table 1** shows the characteristics of non-injured athletes and injured athletes. No significance associations found between injured and un-injured for anthropometric indexes (height, weight and BMI).

Table 1: Characteristics of injured versus non-injured athletes

	N	Not Injured n (%)	Injured† n (%)	p-value
Demographics				
Participants	226	57 (25.2)	169 (74.8)	
Age (Years) *	219	13.6 ± 2.0, 14.0	14.4 ± 1.6, 15.0	0.005
Anthropometric data				
Height (cm)*	98	156.0 ± 10.2, 155.0	160.9 ± 13.1, 160.9	0.147
Weight (kg)*	98	45.3 ± 11.5, 42.7	50.0 ± 12.5, 48.7	0.158
BMI¹	98	18.3 ± 2.5, 18.3	19.2 ± 4.4, 18.5	0.492
Beighton score*	226	1.2 ± 1.7, 0	1.3 ± 1.7, 1	0.482
Contact Vs. Non-Contact				
Contact	132	24 (18.2)	108 (81.8)	0.004
Non-Contact	94	33 (35.1)	61 (64.9)	

Legend: *†, injured once or more; *All score variables were presented as Mean ± SD, Median; BMI¹, Body Mass Index*

Across all sports, 81.6% of football participants presented with at least one injury. The prevalence of injuries in contact sports is significantly higher compared with non-contact sports (81.8% Vs. 64.9%, p=0.004).

Contact sports had a lower injury-free survival time compared with non-contact sports; 127 days (95% CI 93 to 160) versus 176 days (95% CI 118 to 234) (p<0.001). Kaplan-Meier Survival analysis estimates showed that median injury-free survival time for contact sport athletes was greater among BS of 0 athletes (148 days (95% CI 121 to 176)) compared with those with BS 1–5 (90 days (95% CI 81 to 98, p=0.022)).

A gradient of Beighton scoring was associated with an increased risk of injury (HR 1.29; 95% CI 1.05 to 1.59, p=0.015), but no significant association was established between injury severity and Beighton scoring cut-off (0 and 1–5) (p=0.12

DISCUSSION

GJL was associated with injury risk in contact, but not in non-contact sports. This concurs with the findings of Konopinski et al.[21] who found an increased incidence of injuries in hypermobile football players (22 vs 6 per 1000 hours of exposure). In contrast, our results failed to find an increased injury severity in the hypermobile players as documented by Konopinski et al.[21]

Our data analysis in reference to the three commonly used subgrouping classification methods showed a non-significant difference in individual injury risk between the hypermobile athletes and similar injury rates in both the hypermobile and non-hypermobile participants in the complete cohort which concur with the results of Collinge and Simmonds.[5] The distribution of scores in this group is skewed towards a score of 0. Due to the small number of athletes with BS ≥6 (n=7), a meaningful estimate of risk in this category could not be ascertained. In a study,[5] the prevalence of hypermobility was 33.3%, with BS ≥4 or more; this result is not in line with the results of our study where the prevalence was only 3.1%, with BS ≥6. This discrepancy could be explained by the variation of cut-offs of GJL scoring, although BS with cut-off ≥6 is recommended for clinical use.[20]

Our data showed a high prevalence of injury in footballers (81.6%) which extended the findings of Ristolainen et al.[22] (73.4%). Given this relatively high prevalence, we recommend the clinical utility of Beighton screening in this category of athletes.

Previous authors have used Poisson counts and injury incidence rates[21]; however, we have analyzed the data after the methods of Ullah et al.[23], employing survival analysis Cox proportional hazards models that address variances of parameter estimates of recurrent injuries of same subjects.

While this research has documented an association between hyperlaxity and injury likelihood in contact sports, it is not possible to ascribe causation, and the possibility remains that athletes choose sports in some part due to their inherent joint laxity.

Our study of multisport analysis is in-line with the research of Nathan et al.[24] which found no association between hypermobility and sports injury.

The interaction between GJL and variables such as age, gender and ethnicity will make it difficult to ascribe a single cut-off point on the BS. Recent systematic review[25] recommended a BS ≥6 for children screening and a cut-off of 5 of 9 for adults. Variations in cut-off and methodologies have created differences in the results and conclusions obtained from studies about GJL; this will make interstudy comparisons difficult. Until more data is presented examining these aspects, such analyses should be treated with caution.

We report the following limitations. We have no data on training or competition exposure, which reduces the comparability with other studies reporting injury incidence. The link between type of sport to injury profile is still unclear due to high heterogeneity and small sample size of non-contact sports.

CONCLUSION

GJL defined by gradient Beighton scoring, plus involvement in contact sports together influence injury risk in youth athletes. Preseason documentation of joint laxity scoring should be considered specifically for contact sports as injury pre-emptive measure.

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Chapter Five

TRAINING LOAD AND INJURY INCIDENCE OVER ONE SEASON IN ADOLESCENT ARAB TABLE TENNIS PLAYERS: A PILOT STUDY

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ABSTRACT

Background: It has been established that injury incidence data and training load in table tennis is somewhat limited.

Objectives: The purpose of this study was to analyze and report training load and injury incidence. This was established over a full season in highly trained youth table tennis athletes. We further aimed to establish what variables related training load have a statistically significant effect on injury in youth table tennis.

Methods: Data was collected from eight male adolescent table tennis players of Arabic origin. Training and game time were monitored continuously throughout each training session and match. Heartrate was measured throughout and then subsequently analyzed to quantify internal training load.

Results: Players were subjected to an average of 1901h33min ± 44h30min of training time and 140h0min ± 11h29min of game time over the season. Overall injury incidence was 8.3 (95% CI: 4.6–12.0), time-loss injuries 4.4 (95% CI: 1.9–6.9) and growth conditions 2.0 (95% CI: 0.6–3.3) per 1000h. Internal training loads quantified via the Edwards (38) training impulse equation were significantly different between training weeks ($P=0.001$), with lowest values around competition periods ($P< 0.05$). For every extra auxiliary unit of relative training load per minute during training, a significant increase ($P = 0.014$) in injury occurrence was present.

Conclusion: Most of the injuries occurred during the first quarter of the year (65%), when training loads were highest. In conclusion, the results of this preliminary study showed that training loads increase during a season until competition period, with relative training load per minute being linked to the likelihood of injuries. The rate of overuse injuries and growth-related conditions were higher than have been previously reported in adolescents in other racket sports (9,13-15).

Keywords: *Racket Sports, Training Monitoring, Injury Incidence, Training Load, Performance*

BACKGROUND

Table tennis is a complex racket sport characterized by an intermittent activity profile multifaceted in its skill, physiological and cognitive demands, with success dependent on the interaction of these.[1,2] Table tennis matches vary from 20 to 60 minutes and rallies from 3 to 10 seconds in duration, with a work-to-rest ratio of 1:2.[3-6] Numerous matches take place in a single day over successive days in competition and are characterized by repetitive efforts of alternating short spells of high intensity rallies and long bouts of rest in-between, with longer rest periods in-between games.[4,7] The dynamic, explosive and fast-paced nature of the sport emphasizes a significant requirement of high levels of physical abilities. A well-developed anaerobic energy system is vital[5] to cope with the demands of training and competition[4,7] which aids recovery, reduces injury risk and enables players to perform during training/competition.[7] .

Injury incidence data in table tennis is limited and shows that risks of injury in senior and junior[8-10] table tennis players are insignificant compared to team-sports[11,12] and other racket sports.[13-17]. Most injuries are related to muscle tissues or affect the waist and shoulder girdle.[8,10] Other body parts affected are the ankle and spine.[8] Many epidemiology studies have examined the injury incidence in highly trained adolescent athletes in racket sports[9,13-17] through means of questionnaires,[13,15-17], putting into question the validity and reliability of measurements. Therefore, recent studies use a surveillance record to collect data and are deemed more appropriate.[9,14] A study performed by Rejeb et al.[9] prospectively collected injury data on 166 male adolescent athletes, 12–18 years old, from different sports, of which 20 table tennis.[9] The major findings showed high rates of time-loss injuries (87.0%) in youth athletes. Further, it was found that the rate of overuse injuries (70%) and growth-related conditions was higher than other racket sports. However, injury incidences in youth table tennis were found to be the lower compared to squash.

To improve performance, changes in training duration, intensity and frequency are required to adjust training load at various phases during the season.[18] With training load linked to injury rates many studies have found a relationship in elite athletes.[11,12,19-23] Studies investigating the influence of training load on injury rates generally reported a significant correlation between training load and injury, suggesting the harder individuals train, the higher the likelihood of injury[18,22,23] or illness.[23,24] Despite the wealth of research documenting the training-injury in elite sport, there is a lack of research reporting typical training loads and injury in (youth) table tennis. Various measures of training load have been proposed over the years.[25]. However, combining information about training intensity and duration can represent a low-tech method to evaluate training load. Heartrate based methods provide such information and are a reliable source of quantification for cardiovascular load and training intensity in sport.[26] Previous work has reported typical cardiorespiratory and metabolic demands of elite junior players[27] and the influences of playing styles on such parameters.[28] It therefore seems feasible to utilize simple heartrate-based methods to quantify training activities in youth table tennis.

There is a lack of research and understanding surrounding the impact of training/competition on adolescent athletes[29] in tennis athletes. The prescription of training to achieve optimal performance has largely been instinctive and there is a strong belief that increased training time results in increased performance/well-being. Nevertheless, this comes with varying degrees of success and increases the likelihood of injury and overtraining.[19,30] . The effect of training on the physiological adaptation, subsequent performance, and injuries requires optimized training prescription that involves an integrative approach to quantification of playing and training load to provide us with a better framework to understand the demands of playing table tennis in different age groups. Collecting more scientific information could help athlete and coaches effectively improve performance, through modifications in training prescription and training load. Altering frequency, duration, and intensity of training sessions can help decrease injury risk and rates and provide ultimate adaptations to training as well as for competition performance.

OBJECTIVES

Therefore, the purpose of this study was to analyze and report the training load over a season and the injury incidence in highly trained youth table tennis athletes. In addition, we aim to use a Poisson regression model to establish and predict which independent variable related to table tennis has a statistically significant effect on injury.

HYPOTHESIS

We hypothesized as training load and intensity increased pre-competition, the risk of injury in athletes would also display an increase. In addition, training load and relative training load will vary at different time-points during the training season, with higher values observed when less competition was scheduled.

MATERIALS AND METHODS

Selection and Description of Participants

Eight male adolescent table tennis players of Arabic origin [age (mean ± SD) 14.5 ± 1.4 yr., maximal oxygen uptake (VO_2 max) 50.0 ± 6.4 mL.kg.min^{-1}, stature 166.7 ± 6.6 cm, body mass 53.6 ± 7.9 kg, ∑ of 7 skinfolds 9.9 ± 5.1 % body fat and PHV -0.48 ± 1.65] were included in this one-year prospective study (January 2016-January 2017). Players who were full-time members of Aspire Academy and the Qatar table tennis Association took part in the study. These players have been identified as the best young Qatari table tennis players in the country and are recruited to represent the national table tennis Association. As a result, due to our stringent selection process, only players which exhibit exceptional table tennis talent, and the players who successfully pass the selection process and are admitted. Therefore, only eight males fitted the criteria set to ensure training load information and injury information collected was of athletes of national level. All boys had previous clearance from a physician to participate in table tennis having been through medical screening procedures to determine their health and injury status. Written informed consent was sought and obtained from their parents. The study was approved by the Aspire Academy Scientific Committee and Ethics approval was obtained from the IRB of the antidoping laboratory in Qatar and conformed to the recommendations of the Declaration of Helsinki. This study is part of a larger study on growth and maturation of young athletes.

Classification and definition of injury types

All injuries were assessed by a physical therapist (one of the authors) with experience of working within youth Table Tennis at Aspire Academy. Injuries were recorded as a physical complaint requiring the attention of the medical staff which occurred during table tennis training, a strength and conditioning training session or during a competition. Injuries were divided into time-loss (TL) injuries and no time-loss (NTL) injuries. A clinical examination and/or treatment of an athlete which did not result in a full training session or competition being missed was described as a "Medical attention" with NTL injury. A clinical examination and/or treatment of an athlete resulting in a training session or competition being missed the following day(s) was labelled as a TL injury.[31] . The lay-off was calculated by the number of days missed from the date of injury (day zero) until the day of return to full participation in training or competition. Overuse injuries were defined as injuries resulting from insidious onset without a recognizable mechanism[32] and occur during the pubertal phase of adolescence during sports practice and fall under the etiology of growth-related conditions/injuries (e.g. Osgood-Schlatter disease). Growth condition injuries are unique to young athletes and result from an increase in the involvement in sports activities by children and adolescents. A traumatic injury was defined as any injury resulting from a specific and identifiable mechanism, including contact and non-contact circumstances with acute onset[33] falls under other injury types (e.g. muscle strain). Injury severity was defined, based on days of absence from usual sport participation, as slight (1 day), minimal (2–3 days), mild (4–7 days), moderately serious (8–28 days), serious (>28 days–6 months) or long-term (>6 months) in accordance with Timpka et al.[34]

Training Load

Prior to training-data collection, all players completed a multi-stage fitness test (MSFT) to determine their maximal heart rate (HRmax) at the point of self-selected exhaustion, as per previously established methods,[35] used for subsequent training-load analysis. During training, all players were required to wear a HR monitor (Polar H7; Polar Electro, Oy, Kempele, Finland) at all times. Individual training was monitored continuously throughout each daily training session using Bluetooth® Smart technology through real time-data collection, which was delivered to and stored in the Polar Team application (Polar Team 1.0 app; Polar Electro, Oy, Kempele, Finland). All data were collected by Aspire Academy staff who were highly familiar with HR monitoring procedures and values were then entered into the Academy's proprietary training-load database (Smartabase, Fusion Sport, Coopers Plains, Australia). These HR data were subsequently analyzed to quantify internal training load via the Edwards'et al. [36] training impulse (TRIMP) equation:

Edwards' TRIMP: duration in zone 1·1 + duration in zone 2·2 + duration in zone 3·3 + duration in zone 4·4 + duration in zone 5·5

where Zone 1 = 50% to 60% HRmax, Zone 2 = 60% to 70% HRmax, Zone 3 = 70% to 80% HRmax, Zone 4 = 80% to 90% HRmax and Zone 5 = 90% to 100% HRmax.

The Edwards training load is based on a method of heart rate zones to calculate training load. The amount of time spent in each respective pre-defined arbitrary zone, is multiplied by an arbitrary coefficient to quantify training load.

On the 56 occasions (3.6%) where a player did not wear a HR unit during a training session, or the data were deemed unreliable, data were predicted, according to the type of session performed (technical, tactical, match play, physical conditioning) and previously collected data session averages for that athlete. The intensity of training sessions was estimated using the relative training load per minute. This enables to provide a more accurate representation of the intensity of training considering training times significantly differed throughout the season.

Training time

Training duration was determined using both a training diary and heart rate registration records (when appropriate) collected through the Team Polar app, to ensure full agreement. Training times were collected and communicated in hours and minutes daily. The maximal weekly training program of the athletes consisted of 8 training sessions per week which were characterized according to three basic types: 5-6 table tennis specific sessions, 1-2 strength & conditioning sessions and 1 recovery session. All sessions had a maximum duration of 90 min; accounting to a maximum total of 12h per week, ranging on average from 1h 30min to 10h 02min per week (due to competition schedule). Training exposure data from absent and/or ill athletes were not accounted for. The exposure periods to training were during school periods, with athletes not in training during the summer months of June, July and August. The training/competition season at the Academy runs from September to May of the following year. A further breakdown of match exposure times can be found in **Table 1**.

Table 1. *Mean ± SD of monthly training hours per athlete over the course of a year*

Athlete	Jan	Feb	March	April	May	June – Aug	Sept	Oct	Nov	Dec	Total
1	31 ± 4	24 ± 5	38 ± 3	9 ± 2	24 ± 3	n/a	17 ± 2	11 ± 3	30 ± 3	38 ± 2	221
2	32 ± 4	20 ± 5	31 ± 3	21 ± 3	20 ± 1	n/a	16 ± 0	18 ± 4	38 ± 2	24 ± 4	206
3	33 ± 2	33 ± 3	31 ± 1	26 ± 4	45 ± 2	n/a	19 ± 1	26 ± 1	38 ± 4	30 ± 1	286
4	25 ± 4	36 ± 2	31 ± 1	29 ± 4	55 ± 1	n/a	17 ± 1	33 ± 1	38 ± 4	42 ± 1	293
5	20 ± 3	32 ± 3	31 ± 1	32 ± 5	48 ± 3	n/a	20 ± 0	27 ± 3	38 ± 4	38 ± 1	290
6	15 ± 2	19 ± 2	31 ± 1	23 ± 3	33 ± 1	n/a	18 ± 0	32 ± 2	45 ± 3	37 ± 1	242
7	20 ± 2	20 ± 2	31 ± 0	16 ± 2	18 ± 2	n/a	12 ± 1	26 ± 3	29 ± 5	30 ± 2	186
8	28 ± 3	21 ± 4	31 ± 2	25 ± 2	21 ± 1	n/a	15 ± 1	5 ± 2	18 ± 3	31 ± 1	177
Total	26 ± 3	26 ± 4	35 ± 3	23± 4	22 ± 3	n/a	17 ± 2	22 ± 4	34 ± 4	34 ± 2	1902

Game time

During official games (Aspire Academy, Club and Federation), players were unable to wear a HR monitor and video data was only recorded for a small number of games. Therefore, the duration of playing time in such games without video data was predicted, according to previously collected data in junior table tennis matches, which have shown to range from 20 to 40 min on average, depending on the tournament format.[3] The exposure periods of matches were only accounted for during school periods, with matches played during the months of June, July and August not considered for further analysis. The average total games played per athlete over the observed season was 35 ± 23 games; accounting for a total of 17 h 30 min per player over that period.

Statistical Analysis

Data were analyzed using statistical software (SPSS, Chicago, IL, USA). Differences between training weeks were evaluated using a general linear model with repeated measures (time [36 levels]) for measures of training load and relative training load per min. Post hoc comparisons were used for injury type and sport type; Bonferroni correction was applied. To correct violations of sphericity, the degrees of freedom were corrected in a normal way, using Huynh-Feldt ($\varepsilon>0.75$) or Greenhouse-Geisser ($\varepsilon<0.75$) values for ε, as appropriate. Graphical comparisons between means and Bonferroni pairwise comparisons were made where main effects were present. Descriptive statistics were presented as frequencies, proportions (%) and incidence rates were calculated as the number of injuries per 1000 h of exposure time and reported as rates per 1000 training hours. The injury rates were described for each region independently, by injury type, injury severity and type of sport. The results are presented as the mean ± the standard deviation throughout the text unless otherwise stated. Ninety-five percent confidence intervals are presented where appropriate. The alpha level of significance was set at 5%. A Poisson regression model was used to assess the linear relationship between injuries (count) and estimate the regression coefficient using the amount of training hours, training load, relative training load per minute and total of official matches played (independent variables). Poisson regression was deemed appropriate for this data as the Kolmogorov-Smirnov test for normality showed injury distribution to follow Poisson distribution.

RESULTS

Throughout the 1-season study period, 8 athletes were subjected on average to 237 h 42 min ± 16 h 15 min of training (table tennis specific, strength & conditioning or recovery sessions) and 17h 30min ± 11h 29min of game time. A further breakdown of athlete training times can be found in **Table 1** From these 8 players, 6 (75%) players reported one or more injuries totaling 17 injuries. Of these, 9 (53.0%) were TL injuries and 47% NTL. Overuse injuries accounted for 56%, from all the TL injuries and the overall growth-related injuries incidence was 24%.

The overall injury incidence was 8.3 (95% confidence interval CI: 4.6–12.0) per 1000 h of exposure, accounting for 2.1 injuries per athlete. TL injuries had an incidence of 4.4 (95% CI: 1.9–6.9) per 1000 h exposure and NTL 3.9 (95% CI: 1.6–6.3) per 1000 h exposure. Overall growth-related injuries had an incidence of 2.0 (95% CI: 0.6–3.3). Further details on injury incidence are presented in Table 2.

Table 2. Injury incidence given as the number of injuries per 1000 h of exposure.

Variable	Injuries, n (%)	Exposure, h	Incidence/1000h (95% CI)
All injuries	17 (100.0)	2041	8.3 (4.6-12.0)
No Time loss	8 (47.0)	2041	3.9 (1.6-6.3)
Time loss	9 (53.0)	2041	4.4 (1.9- 6.9)
Acute time loss	4 (44.0)	2041	2.0 (0.6- 3.3)
Overuse time loss	5 (56.0)	2041	2.4 (0.8- 4.1)
Growth Conditions	4 (24.0)	2041	2.0 (0.6- 3.3)

Location and diagnosis of injury

The majority of injuries with TL were located in the lower extremities (n = 5, 56.0%) and affected the hip and groin the most. The spine was the most common region for overuse injuries, accounting for 24% of all overuse injuries with most of these causing TL (**Table 3**). Muscle spasm was the most common acute injury, accounting for 38% of all acute injuries reported. The most frequently injured body part structures were the apophysis with 24% of all injuries related to this condition.

Injuries with TL located in the lower extremities showed an overall incidence of 1.5 (60%, 95% CI: 0.5–2.4) per 1000 h of exposure. The apophysis showed an incidence of 2.0 (95% CI: 0.6–3.3).

Table 3. Location of injury, diagnosis of injury and severity of injury, which was defined, based on days of absence from usual sport participation, as slight (1 day), minimal (2–3 days), mild (4–7 days), moderately serious (8–28 days), serious (>28 days–6 months) or long-term (>6 months)

Injury Number	Location of Injury	Diagnosis of Injury	Severity of Injury
1	Back	Cramp	TL, mild
2	Back	Mechanical pain	NTL
3	Arm	Contusion	NTL
4	Elbow	Osteochondrosis	NTL
5	Elbow	Muscle pain	NTL
6	Neck	Spasm	TL, slight
7	Back	Osteochondrosis	TL, moderately serious
8	Neck	Cramp	NTL
9	Ankle	Sprain	TL, slight
10	Shoulder	Inflammation	NTL
11	Hand	Contusion	TL, slight
12	Back	Mechanical pain	TL, minimal
13	Neck	Spasm	NTL
14	knee	Contusion	TL, minimal
15	Knee	Osteochondrosis	NTL
16	Back	Osteochondrosis	TL, moderately serious
17	Shoulder	Muscle pain	TL, slight

Injury Severity

In this study the highest incidence of injury was sustained in the month of March (n=5, 29%). No injuries were reported in May, October, November or December. The first quarter of the year (Jan-March) accounted for 11 out of 17 injuries (65%) during periods of increased daily training and intensities and direct contact with physio (training camps). Our results showed that the most reported injuries (29.0%) were minor. Within the minor injuries, the minimal (40%) and mild (60%) were the most frequent. 12.0% of all injuries were moderately serious injury. No serious injury was found in this study. The overall average of days lost through injury over the course of a year amounted to 2.4 days, while the median of days lost through injury over the course of a year amounted to 1 day. The longest periods of time loss due to injury were 12 and 16 days reported by the same athlete because of osteochondrosis.

Training Loads

Mean (± SD) values for Edwards training load were significantly different between training weeks (*p=0.001*; see **Figure 1**). Training loads mid-season (weeks 38 and 39) were significantly higher compared to training weeks around competition periods *(p<0.05).* Relative training load per min was also significantly different between training weeks (*p=0.007*; see **Figure 1***).* The weeks leading up to competition showed lower relative training loads per min compared to other weeks *(p<0.05).*

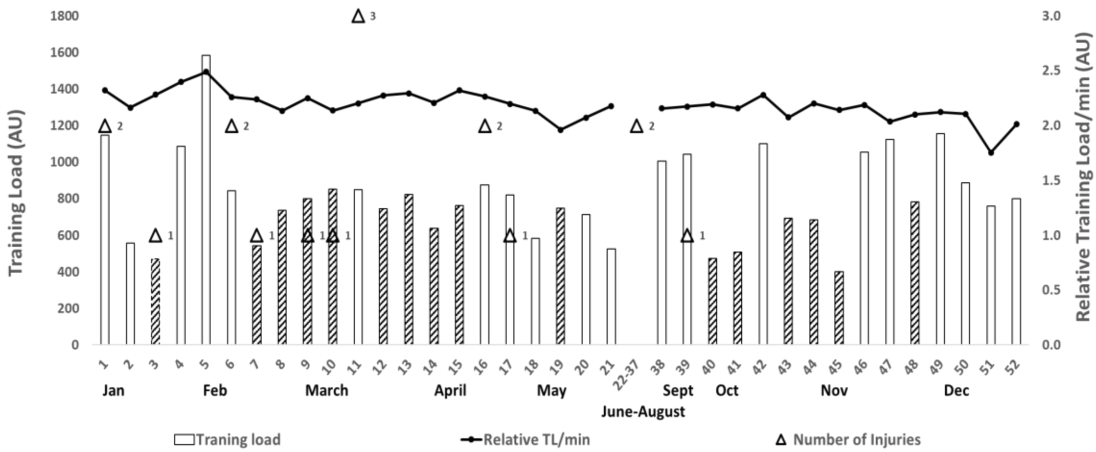

Figure 1. Weekly training load and average weekly relative training load/min over the course of a year in youth adolescent Table Tennis athletes. Pattern fills represent the weeks during which the competitive season occurs.

Poisson Regression

Poisson regression analysis using one-year of training data to analyze and establish the association between monthly injury incidence and estimate the regression coefficients of the amount of training hours, training load, relative training load per minute and total of official matches played. The data has shown to follow normal Poisson distribution *(p=0.404)* and indicates that our model is statistically significant *(p=0.0005).* For every extra auxiliary unit of relative training load per minute during training, a significant increase (*p=0.014*) in injury was present. However, the amount of training time, training load, and total matches played, did not explain injury *($p<0.05$).*

DISCUSSION

The purpose of this study was to report the yearly training load and injury incidence in highly trained youth table tennis athletes and assess if any relationship existed with injury occurrence. Previous studies have investigated the injury incidence in table tennis athletes (youth and senior) without reporting the training load over the course of a competitive season. Also, to the authors' knowledge, this represents the first report of typical training loads experienced by adolescent table tennis players over the course of a season or looked at estimating the regression coefficients of variables related to injury.

The results of this study demonstrate that differences in training load are evident during a training season. Training over the course of a year is designed to elicit improvements in strength, power, endurance, skill, technical and tactical readiness of players to maximize performance.[11,37] It has previously been found that an increase in training load generally shows a higher the likelihood of injury[18,22,23] and illness[23,24] in adult athletes. Data in young athletes in other sports have suggested that training volume was positively correlated to time to first injury report.[38] However, Brooks et al.[11] found that optimizing the recovery process after training and playing helps arbitrate the negative impact of higher training loads resulting in the low injury incidence in athletes. Furthermore, our data are in line with previous work in table tennis presenting relatively low occurrences of injury incidence in adult athletes.[8,10] It is interesting to notice that most of the injuries in this cohort occurred during the 1st quarter of the year (65%), when training loads were significantly higher. Through Poisson regression analysis, we further established that the relative training load per minute partly explained injury occurrence but not overall training loads, the amount of training hours, or the total amount of games played. Prior to competition, the coaching staff places a large focus on table tennis specific agility and specifically on improving or maintaining endurance capacity, which results in increased relative training loads and acute injuries during this time-period. The progressive increase in training load from September to January reflects the typical progression from pre-season to competitions also observed in other sports and the consequent increase in acute injuries has been also observed in young tennis players[17] with a potential link to training load.[39] Therefore, individually monitoring relative training load per session and fatigue in players can help with applying more individualized training sessions and reducing injury. In this preliminary study, the rate of injury with TL was 53% with an injury incidence rate of 8.3 per 1000 h of table tennis exposure. Data on incidence of injury in middle school sports collected over a 20-year period reported similar rates of TL injuries of 45.1% but exhibited a lower injury incidence rate of 2.7 per 1000 h of athletic exposure.[40] Other investigations found the prevalence of injuries with TL to be higher in elite youth soccer players ranging from 63.4% - 66.5%.[41,42] The discrepancies between studies in the literature may be explained by inconsistencies with respect to possibility of reporting bias.[9] In the study conducted by Beachy and Rauh[39] some athletes may have had injuries that were not reported to athletic training staff. Therefore, approximation of the number of injuries could have led to an underestimation of injury incidence rates. Further, the variations in methods utilized to investigate and collect data on injury incidence explains the lack of well-controlled studies conducted, which are available in the literature. The large differences between data collection methods make comparisons difficult. Further, previous studies did not examine the injury characteristics in youth table tennis athletes; therefore, make it difficult to compare our findings with similar cohorts.

Injury incidence in table tennis shows injuries in table tennis to be insignificant when compared to other sport disciplines in youth and senior athletes.[8,9,13-17] It has been previously established that TL injuries in youth table tennis accounted for 89.1% with an injury incidence rate of 4.3 per 1000 h of table tennis exposure.[9] However, our results found injury incidence rates to be much higher at 8.3 per 1000 h of table tennis exposure in our cohort. In this study, all training and competition data was recorded using heart rate software records and a registration record, respectively. Only in 3.6% of training sessions did players not wear a HR unit, or was the data deemed unreliable because of Bluetooth connectivity issues data which meant it had to be predicted, according to the type of session performed (technical, tactical, match play, physical conditioning) and previously collected data averages for the type of session. The analysis of training load indicated that overall, the intensity of the training sessions was moderate to low (report time spent in various zones and Edwards TRIMP). This is expected, as previous work reported the cardiovascular demands of youth table tennis competitions to be relatively low.[27] Therefore, if technical and match play represents the main bulk of training activities, it is unlikely that table tennis training alone can represent a training stimulus capable of inducing improvements in aerobic capacity.

The prevalence of overuse injuries acquisition in the present study was 56%, and higher than other studies in youth athletes, where estimates of the proportion of injuries because of overuse range from 13.4% to 54%[13-17,43] and like youth athletes in table tennis (62.2%) in similar cohorts.[9] The prevalence of overuse injury rates in table tennis is attributed to the characteristics of the sport, as the frequency and type of overuse injuries in elite youth athletes are related to type of training and conditioning.[44] The peculiarity of table tennis as a sport of many balls repetition bouts is an underpinning cause of the higher rate of overuse injuries when compared to other sports.[9] Overuse injuries in table tennis are because of the cumulative, repetitive sub maximal micro trauma nature of the sport, where inadequate time for recovery between stress episodes is provided to players.[8,45] Understanding the significance of excessive loads on the human body and how they are distributed, the sports-injury mechanisms and the biochemical responses of the body tissues impacted will help further knowledge surrounding overuse injuries in table tennis.[8] While our observations only include cardiovascular demands of each training sessions, they are limited by the absence of more information about workload with reference to changes of directions and accelerations/decelerations which may be the main cause of injury in the lower limbs. For this reason, implementation of wearable technology for training monitoring[46] might allow better quantification of table tennis demands and help explain the occurrence of acute and chronic injuries in this cohort.

The results of our study observing this small cohort of table tennis players indicated a prevalence of growth-related conditions of 24%, consistent with results found in similar study looking at youth table tennis athletes in a similar cohort.[9] Although our results highly differ from findings in other studies where incidence of growth-related conditions ranged from 0% to 16.8%,[42,47] it is difficult to discuss the discrepancies between studies, however large differences exist in data collection procedures, maturation status and training environments. As this work was part of day to day support to the table tennis youth team, it is possible that the daily collection of data of this work is more accurate than retrospective cohort studies. Growth and maturation injuries do occur more commonly during sudden periods of growth and constitute additional risk factors for injury occurrence in youth athletes.[48] These cause additional concerns that require prevention strategies such as growth monitoring for long-term consequences to help decrease the long-term injury risk. Therefore, it is important to take a closer look at injury inciting factors and prevention plans for youth athletes for injury prevention/decrease.[9,14]

It was established that there were no differences in the amount of injuries in the lower extremities (35%) when compared to the higher extremities (35%), and spinal injuries consisted of the rest (30%). Research which has previously looked at injuries in table tennis found that the highest number of injuries affect the shoulder girdle.[8,10] We also found that shoulder joint injuries were a common injury especially in our junior athletes (15-17 years). It is believed that due to the increase in specific table tennis skill demands in training required at this age the shoulder joints are negatively affected as a result. The short, abrupt and rapid movements required during strokes result in repetitive sub-maximal trauma of the shoulder joint due to lack of recovery and continuous training/competition schedules. Further, the processes of growth and maturation, and the physical and physiological differences between children and adults in table tennis further explains differences found in injury rates, injury severity and affected areas of injury.

Fortunately, in our cohort, 88% injuries were minor in nature and required less a week to return to sports activity. Table tennis is an ideal sport for adolescents because of its extremely low injury risk and severity[8] and our data support this view. The severity of injuries in table tennis are considerably lower than other sports[9] and further justify the use of table tennis as a sport for rehabilitation.[8] Furthermore, the relatively low cardiovascular demands might suggest its implementation in increasing activity patterns in inactive children. However, from a performance standpoint, it is fundamental to consider additional conditioning activities to improve work capacity and the ability to sustain more intense training and competition situations.

CONCLUSION

In conclusion, the results of this preliminary study showed that training loads increase during a season until competitions in a young cohort of table tennis players with relative training loads being linked to the likelihood of injuries. The content and characteristics of training activities indicate a low to moderate cardiovascular demand which reflects competitive demands in this age group. Further, the rate of overuse injuries and injuries as a result growth-related conditions in our adolescent table tennis athletes was higher than previously reported in adolescents in other sports. Considering the peculiarity of youth adolescent athletes, it is important to improve the planning of training activities improving the understanding of the link between training load and injury occurrence. We hope that the results of this preliminary observation can be used as a reference for comparative studies in other and larger cohorts and as an initial input to conduct further studies in this popular sport.

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The authors received no financial interests related to the material in the manuscript.

CONFLICT OF INTEREST

The authors of this study certify that they have NO affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

ADDITIONAL INFORMATION

The first two authors contributed equally to this paper.

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Chapter Six

GENERAL DISCUSSION

Sport carries an inherent risk of injury, which for young athletes may have both immediate and long-term consequences.[1] Negative experiences can result in a range of harmful outcomes including injury. Injury in an adolescent athlete can sometimes be identified not only in the interruption of competitive activities, but also as the end of participation to physical activity and sport.[2]

Alas, sport participation is an established cause of acute and overuse injuries in childhood and adolescence.[3-5]

Overuse injuries represent a substantial injury burden in adolescent athletes.[4-10] Athletes who had overuse injuries lost 54% more time from training and competition than those who had acute injuries.[11]

Since most of the research has focused purely on adult elite athletes, little is known about injury epidemiology among young elite athletes[12,13]. Therefore, a better insight of epidemiology of adolescent athletes is warranted. Only few studies, mostly in soccer, were performed in Middle Eastern youth athletes reporting prevalence rates and characteristics of injury.[5,14]

Also, in countries where the talent pools are limited (such as Qatar for example), the development of adolescent athletes should be directed to preserve the best talents (i.e. minimize injury) and develop them to compete at the senior level.[2]

More in-depth knowledge of athletes' injury experience may further increase our knowledge of management approaches in prevention and treatment of young elite athletes and possibly lead to identifying gaps in prevention and injury mitigation in adolescent athletes.

This project aimed at identifying injury incidence, type and characteristics in a cohort of highly trained Middle- Eastern adolescent multisport athletes. The association between maturation level and injury was investigated. In addition, Generalized joint laxity of the adolescent athlete, was also investigated.

In this discussion, we contemplate the main findings of our studies, in-light of their strengths and limitations. We consider what clinical implications these findings might add to the current body of scientific knowledge and make recommendations for future research.

THE EXTENT OF THE PROBLEM

Identifying prevalence, incidence and severity of an injury; e.g. "the extent of the problem" is the first step in the four-step process of the injury prevention model of van Mechelen[15]. In **chapter two** we examined the incidence and pattern of injuries in young Middle Eastern elite multi-sport athletes. Major findings were high rates of injuries with subsequent TL (87%), high rates of overuse injuries (50.3%). Most of the overuse injuries were minor (53%) and located in the lower limbs (67%).

Our study also revealed a higher rate of growth-related conditions (20.2%) in contrast with similar studies on soccer players which found lower rates (%) of growth injuries. The discrepancies between studies are more likely attributed to our screening and early recognition of growth-related conditions through an implemented monitoring plan, instead of the conventional method of injury reporting complaints to the healthcare provider.

In our study the high rate of overuse injuries was consistent with the results of Malisoux et al.[16] on collegial youth athletes but in contrast to the study results on adolescent soccer players performed by Materne et al.[5] and Le Gall.[17] These Contrasting results from different studies could be attributed to the characteristics of the sport, e.g. contact and team sport versus individual sport, as the frequency and type of overuse injuries in elite young athletes vary by sport, and sports-related training and conditioning. Injury definition adopted in the study design could also impact the reporting and subsequently the rate of overuse injuries. In fact, broad definitions (e.g. "medical attention" or "any physical complaint") are more appropriate for capturing overuse and mild conditions.[18]

What is an overuse injury?

Sports injuries are typically classified as being either an acute (traumatic) or an overuse injury. Theoretically, the difference between the two types is the nature of the energy transfer that caused them. For acute injuries the energy transfer is instantaneous, whereas for overuse injuries it is accumulated over time.[19]

Timpka et al.[20] defined overuse as ''loss or abnormality of bodily structure or functioning resulting from repeated bouts of physical load without adequate recovery periods in association with sports training or competition that following examination is diagnosed by a clinical professional as a medically recognized disease or syndrome''.

The specific definition of overuse injury is most commonly based on the concept of an injury occurring in the absence of a single, identifiable traumatic cause.[21] Overuse injuries occur when a tissue is injured due to repetitive submaximal loading. The process starts when repetitive activity fatigues a specific structure such as tendon or bone. Cumulative microtrauma from further repetitive activity ultimately causes clinical injury.[11]

More recently a replacement for the term 'overuse' with 'training load error' has been proposed.[22]

In our academy setting, recognized as a high-performance sports environment, with its structured weekly training, the demands of high-level sport are imposed on athletes during periods of growth and maturation, which may have caused higher rates of growth injuries. This is a compelling example where a closer look at injury inciting factors and prevention plans for youth athletes are needed. The high prevalence of growth-related injuries is also more likely attributed to our enhanced reporting of early signs and symptoms in conjunction with an implemented pre-season monitoring plan.

OVERUSE INJURIES- METHODOLOGICAL CONSIDERATION

Current surveillance methods in sports injury epidemiology studies, which rely heavily on time loss for injury definitions and severity measurement, may underestimate overuse injuries' true impact. This is because athletes often continue to participate in sport despite the existence of overuse injuries.[23-25]

The typical presentation and characteristics of overuse injuries makes it difficult to record in epidemiological studies. In all cases, the injury recorder needs to make a clinical judgement based on the theoretical definition of overuse and acute injuries. As accurate injury registration is a fundamental component of all steps in the sequence of injury prevention, an inability to record overuse injuries in a valid and reliable way hinders progress towards prevention.[26] Although no injury surveillance system will capture all injuries, estimating the direction and extent of bias by underreporting is important.[27]

This is consistent with the "all physical complaints" definition recommended in most consensus statements.[25,28,29] (**Figure 1**)

However, "all physical complaints" adopted definition might be criticized for overestimating the injury incidence rate. Despite this limitation it appears safe to recommend that the injury definition and data-collection methods are critically important in determining the magnitude of injuries in a surveillance study.

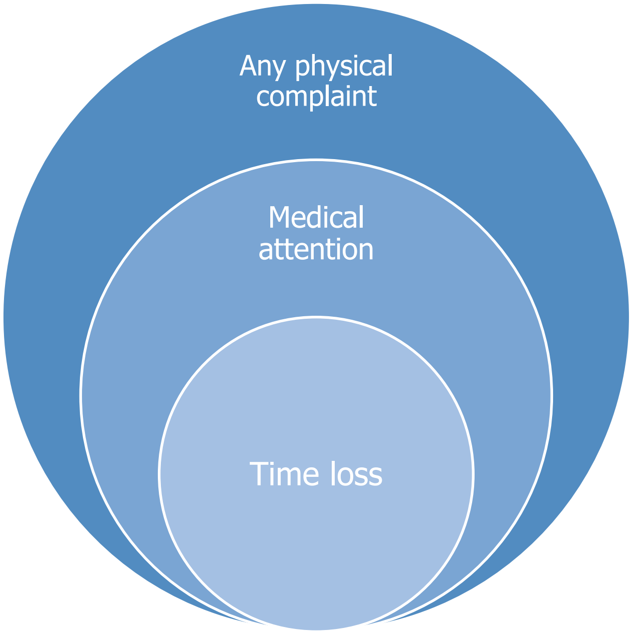


Figure 1: Venn diagram over a supposed distribution of the number of injuries for each injury definition

As per van Mechelen's[15] injury prevention model, when specific injury problems are identified, risk factors should be investigated, and prevention interventions tested.[15] An understanding of the risk factors contributing to overuse injuries is the cornerstone of prevention. These risk factors have typically been classified as non-modifiable and modifiable factors. In children and adolescents, issues specific to the immature musculoskeletal system deserve special consideration.[11]

The inherent risk of sports-related injury is heightened at various stages of growth and maturation.[7,30]

YOUTH SPORT INJURIES: NON-MODIFIABLE RISK FACTORS- GROWTH AND MATURATION-HYPERMOBILITY

The role of growth and maturation

In **chapter three part one** we examined the injury incidence according to maturity level. We found that biological maturity status and height gradient play both a significant role in injury risk profiles of highly trained youth athletes. The results of the study showed that athletes maturing at a younger age are at a significantly greater risk of injury, more than two-fold, compared with their later maturing counterparts. Taller athletes were also found to be significantly more at risk of injury. As explained by Backous et al.[31] a more aggressive play and greater risk taking associated with maturity may be reflected by the high incidence of contusion injuries in the clearly mature soccer players. Our study on the effect of maturity status on injury characteristics showed that EM athletes (incidence 1.5, 95% [0.6 to 3.3]), presented with significantly higher ($p=0.018$) hematoma/contusion/bruise injury type compared to their NM (incidence 0.4, 95% [0.3 to 0.6]) peers.

The results of maturity effect on injury were analyzed with two different methods, an invasive method (SA) and via a non-invasive method (anthropometric measurements: PHV and APHV). The number of athletes in every maturity status category differed according to the method of maturity assessment used for maturity classification (SA-Fels Vs. PHV-APHV). Comparing maturity groups, using SA/Fels method, the incidence of injuries among early maturing athletes was 3.5 per athlete (38 injuries from 11 players) which was twice compared to late maturing athletes with an incidence of 1.8 per athlete (33 injuries form 18 players) ($p=0.0068$). After adjusting for sport type, the early mature and the normal maturers had greater risk of injury compared to later maturers, but marginally significant ($p<0.10$).

The significance of individual differences in biological maturation upon children's involvement in sport and physical activity are well documented.[32] Michaud et al.[33] showed that children display an increase in sports related injury occurrence as they mature and that the risk of injury is linked to biological development (pubertal stage) more so than to actual size and weight, body mass index, or chronological age of the individual.

Read et al.[7] reported that the preceding growth in skeletal structures provides a stimulus for morphological adaptation of muscle tissue, thus an inherent time lag is present between the rate of bone growth and subsequent muscle lengthening. This has connotations for the incidence of traction apophyseal injuries in youth athletes due to subsequent stiffness. This has a direct clinical implication for injury prevention through the implementation of personalized stretching for targeted at-risk athlete(s) and the implementation of structured monitoring systems. The implementation of a weekly monitoring is required for all athletes presenting symptoms requiring no training time-loss but some restrictions during sessions, and this in close collaboration with their coaches and monthly follow-up of fully discharged athletes after periods of limited training sessions.

Staff around adolescent athletes should be aware of the presence of musculoskeletal growth lags following the onset of a growth spurt up to, and around the period of peak height velocity, to ensure that the occurrence of overuse and apophyseal injuries is mitigated during these critical periods. This could be achieved by the periodical implementation of a sound and consistent anthropometrical, and musculoskeletal testing period (e.g. every three months). This strategy constitutes a longitudinal follow-up and updates maturational status and detects early symptoms of negative effects of a maladapted training on immature athletes.

Late maturity level: Higher odds of growth-related injuries (Osteochondrosis)

In chapter three part two an investigation was carried out to examine sports-related injuries incidence of youth athletes and their characteristics according to maturity status. Major findings showed that athletes maturing at an older age are at a significantly higher risk of growth-related overuse injuries, compared with their normal maturing counterparts. Similarly, in his study on soccer youth players Le Gall[9] reported a significantly higher incidence of osteochondroses in normal and late maturers (0.3 vs 0.7 vs 0.9, P= 0.014). According to Van Der Sluis[34], later maturing players had a significantly higher overuse injury incidence than their earlier maturing counterparts both in the year before Peak Height Velocity and the year of Peak Height Velocity.

Late mature adolescents' progress more rapidly through puberty (i.e., a shorter period of pubertal growth). This is believed to be due to testosterone, which stimulates bone formation during pubertal growth. Prolonged prepubertal growth and a shorter period of pubertal growth duration may be associated with a relatively lesser amount of periosteal bone formation in late mature males.[14,35] Limb length, mass, and moment of inertia increase greatly during growth, but not in a linear manner. The relatively short pubertal growth period of late mature athletes may impose sudden demands for modifications in muscle activation patterns to accommodate changing limb dynamics.[14,36] Osteochondrosis is a disorder of primary and secondary growth centers, or lesions at the apophyseal or epiphyseal growth areas of bones.[37] Osteochondrosis as growth-related injuries represent the mainstay of overuse injuries in adolescents.[4,38] The incidence of osteochondrosis among all overuse injuries seen in the 15-year-old and younger athletes was reported to be between 37% and 40%.[37] The pediatric skeleton lends itself to injuries unique to the young athlete, including various apophysitis and osteochondrosis.[38]

The results of the current study demonstrated that highly trained athletes who mature later than their peers experience a significantly higher rate of growth-related injuries injury incidence aka osteochondroses which represent the mainstay of overuse injuries. However, our study didn't analyze whether such type of injuries occur during or around PHV. Such valuable missing information could link the pathoanatomic site of osteochondrosis with the injury timing. A study to investigate the influence of maturation timing in relation to growth-related injuries occurrence should be warranted.

Sample size and the derived numbers of athletes in each maturity level category represent a limitation of this study. Although, our study found a significant association between growth- related injury type and late maturity level, a more in-depth statistical inference should in the future be warranted.

Hypermobility: Help or hindrance?

Chapter four a study was carried out to evaluate the relationships between GJL (measured by the Beighton scoring (BS)) and the risk of injury among youth athletes engaged in different sports activities. Our study showed that greater GJL, defined by gradient BS, plus involvement in contact sports significantly influences injury risk in youth athletes. In individual non-contact sport like gymnastics, it is unusual for any athlete to reach international standards without being defined as hypermobile according to the Beighton classification. Thus, GJL is an asset with no proven association to injury. In fact, the findings within this study are inconclusive as hypermobility does not warrant an injury free individual athlete. Conversely, GJL may heighten the odds of injury for hypermobile adolescents engaged in contact sports. These results corroborated with previous studies showing that adolescent athletes who are involved in contact sports have a higher risk of injury.

An analysis of the Beighton score as a proxy of generalized joint laxity (GJL) and its probable correlation with age across all participants (n=226) was performed. Pearson's correlation did not indicate any influence of age on GJL in our study cohort (age between 10-18 years old) ($r= 0.015$, $p=0.822$, $r^2=0$).

Our study found that joint laxity and its Beighton score (BS) remained unchanged from the age of 10 till 12, with a subsequent sharp decline (dip curve) at the age of 14, followed by a (BS)"spiking" at 16 years old. This was then followed by a decline till the age of 18 years old in this cohort.

A significant decline in joint laxity was found among the age group of 14 years across all participants (n=226), this finding was also confirmed within soccer players subgroup (n=126). This finding is in agreement with the findings of many studies of 13-14-year-old athletes (Singh 2017; Clinch 2011). Reports as to why such a difference might exist around this age (14 years old), pubertal age, are thought to pertain to hormonal changes and or flexibility and puberty affecting joint mobility.

It is possible also that altered kinetic flexibility during pubertal age may have contributed to a perceived reduction in joint laxity and could explain the low prevalence of hypermobility among boys in our study.

*Table I. Age (Grouping) * Beighton Score (Cut-offs) Crosstabulation*

	Beighton Score (Cut-offs)		
Age group	**0-3**	**≥ 4.00**	**Total**
10-12	77.3%	22.7%	100.0%
13-15	94.3%	5.7%	100.0%
16-18	80.8%	19.2%	100.0%
Total	**87.7%**	**12.3%**	**100.0%**

p- value= 0.003

The overall incidence of injuries using 0-3 Beighton score cut-off was identical to 4+ cut-off. However, the incidence of sprain type injury was significantly (p= 0.039) associated with Beighton score 0-3 cut-off. Overall incidence of joint injuries was higher among the cut-off 0-3 group compared to 4+, but this was not statistically significant (p=0.07). Our results contradicted somewhat Pacey and coworkers.[39] who reported that sport participants with joint hyperlaxity have an increased risk of knee joint injury during contact activities. Although ligamentous laxity is believed to predispose overuse injuries, this assumption was not reflected in our study. No association was found between injury mechanism (overuse Vs. acute) and BS.

Youth sport injuries: modifiable risk factors- exposure volume- training load

In chapter two the training volume exposure was found to be significantly associated with risk of overuse injury. Several other studies have shown this direct relationship between the risk of injury and the number of hours of training.[33,40]

However, in our study, we reported a training exposure volume which is inconsistent (less than 3 times) with the expected exposure volume hours of training as detailed in the methods and the factual figure presented in the results section.

In fact, in this study set up (Aspire academy), all enrolled participants should go through 8 training sessions and a total of 16 h per week. Therefore, ideally a player can accumulate 740 hours- season as mentioned in the methods. However, because not all participants were followed in the study for all 5 seasons (as per the flowchart describing the inclusion and flow of participants throughout the study), either unjustified absence and or subsequent to time-loss injuries; the target of 740 hours- season was definitely not achieved which represented a limitation of our study on injury incidence of highly trained youth. Over the five seasons individual athlete exposure averaged 701±448 hours. Despite the inconsistency between expected training volume (hours) and the latter factual figures, it's worth noting that our findings on injury incidence are within the range of other studies findings.

High training volume exposure leads to a fatigued state and overstressed structures and is hypothesized as the underpinning cause of injuries. In fact, fatigue following extended training volume has been reported to increase known markers of injury risk, which may subsequently affect dynamic joint stabilization.[41] Studies on soccer players have shown that injuries occurred more often towards the end of second half,[42] with this timeframe indicative of reduced neuromuscular function and control.[43]

Carefully planned recovery sessions, and rest between training sessions should be envisaged. Also, the institution of an adequate training load monitoring system is a necessary measure to quantify training volume and how young athletes cope with stressors from training exposure. A recommendation to manage the transition from part-time club level into full-time training (2 max training exposure hours per day to twice 2-h training a day) may be highly important to allow a progressive accumulation of training at a young age with limited risks.

In chapter five a small-scale investigation was carried out to refine the methodology (appropriate choice of training load monitoring/or combination) for a larger scale study as part of research project at the academy sports department aiming to investigate youth, sports participation, apophyseal-physeal injury, optimal loading and training load dose response. An athlete's prior training history, development, injury record, sport category and level of participation will have a major influence on their training-load tolerance and subsequent injury risk. Taking this into account, it is important to conduct research in order to determine the injury risk ranges; with the best-case scenario being an in-house study of our athlete population. We conducted an in-house pilot study to investigate training load variable (heart rate) to injury occurrence in youth Table Tennis athletes. We also aimed to determine the ranges of optimal workload and lowest injury risk called "sweet spots".[44] The results of this pilot study revealed that most injuries occurred in conjunction with enhanced training loads, during the first trimester of the season. Previous studies have shown links between training load and injury in adolescent populations.[45]

Monitoring athlete training loads help protect them from injury and ill health.[46] The quantification of training and competition loads in children and adolescents is important as evidence suggests a relationship between high volumes of training in adolescent years (13 to 14 years) and injury.[47] Overwhelming overuse and growth-related injuries found in our population require a diligent and adapted athlete training load monitoring as this can aid in determining whether an athlete is adapting to a training program and thus minimizing the risk of developing non-functional overreaching injury. A primary goal of load monitoring should be to assist and inform the coach/manager and clinician decision maker on player's availability for training, rest between sessions and design recovery strategies.[48] Training should be personalized taking into consideration the individual athletes' aptitude , physical condition and biological development to optimize the benefits and curb negative effects incurred from an untimely strength, and conditioning training and non-optimal loading. Recent studies[19] suggest that the management of load considering the accumulation over the last week (acute) and month (chronic) to measure the training stress balance[49] and avoiding spikes in training of more than 10%, might represent a successful training strategy to avoid injuries. Summarizing information from different monitoring models in meaningful outcomes can inform and affect a performance plan.

In our study, as part of training load monitoring, we used heart rate (HR) data, collected and analyzed to quantify internal training load via the Edwards' training impulse (TRIMP). The Edwards training load is based on a method of heart rate zones as explained in the study methods. We calculated the acute chronic workload ratio (ACWR) for all participants over the whole study period (1 season). It was established that athletes with an ACWR ranging between 1.3- 2.0 were at lowest relative injury risk, often described as the "the sweet spot". These findings are in contrast with previously reported "sweet-spot" ranges (0.8- 1.3) by Gabbett.[44] In fact, the ACWR "sweet-spot" ranges derived from rugby league players which was not found suitable workload monitoring tool for other sports.[50]

Internal and external training load monitoring should be used in combination to provide greater insight to training stress. The uncoupling of internal and external loads may aid in determining if an athlete is fatigued or not.[51]

The use of objective data with youth athletes is fundamental for appropriate training load monitoring. In this study we used HR, and although Heart rate (HR) monitoring is a scientifically sound method and frequently used, to estimate internal training load it has some important limitations. The measure is based on the linear relationship between HR and the rate of oxygen consumption during steady state/aerobic exercise while in competitive level table tennis sport periods of rest, and periods of short submaximal and maximal efforts with high HR values constantly fluctuate during training and competition activities.

Therefore, analyzing training load primarily through HR monitoring methods in a sport like table tennis can be misleading, although it can provide a general physiological insight of an overall training load for sessions or competitive events. However, HR cannot be so effectively used to quantify internal load during short-duration high-intensity/anaerobic activities characteristically performed by table tennis players during training/competition. The rate of perceived exertion (RPE), an appropriate alternative method to quantify the internal load is proposed. Despite the subjective nature of RPE, it has been shown to correlate well with a number of HR-based internal load when multiplied by the duration of the session[52], which could justify its use as an estimate of internal physiological and biomechanical load (perceived effort).[53]

However, Murray[45] criticized that the use of RPE may be of limited application as he questions the ability of young people to be able to reliably assess the perceived exertion, as well as potential language and cultural issues with anchoring scales when translated from the original constructs.

It is also recommended to opt for training periodization and the so-called '10% rule' as guidelines for a maximum training progression.[54] This is commonly used by runners, coaches and clinicians as a guideline for a maximum increase in training load per week.[55] Knowledge of an athlete's training is helpful as unsound practices and abrupt changes may lead to overuse injuries. Knowledge of the number and types of sport specific core training per week e.g. number of pitches for throwing athletes and weekly mileage for runners as well as recent changes to their program should be documented.[56]

Injury prevention strategies

Clinical framework

Although athletes are inherently predisposed to musculoskeletal injuries by participating in sports, etiology models have illustrated how susceptibility is influenced by repeat interactions between the athlete (i.e. nonmodifiable factors) and environmental stimuli (i.e. modifiable factors).[57] An operational clinical framework to guide practitioners in continuously managing injury risk whilst considering factors unique to the athletes sport and profile has yet to be proposed.[58] The operational framework may be useful in managing youth injury throughout the sporting season by considering each athlete's characteristics before designing an appropriate preventative plan. However, all futuristic prevention and treatment plans start with the right diagnostic tool but not relying solely on pathoanatomic diagnosis. The concept of tissue "irritability" is meant to reflect the tissue's ability to handle physical stress.[59] Three stages of tissue irritability defined as following: high irritability defined with high pain (>5/10) and identified high functional impairment related to sport context; moderate irritability defined with moderate pain (3-5/10) and moderate functional capacity and low irritability defined with low pain (0-2/10) and low identified functional impairment.

The staging of tissue irritability is based on the pain score (e.g. NRS>5/10) and the level of identified functional impairment according to the athlete' sport.

Our study on maturation level and injury characteristics revealed that late maturers are at higher risk of osteochondrosis such as Osgood-Schlatter disease (OSD) and other traction apophysitis. In our clinical setting, we managed such type of injuries based on "tissue irritability concept" three stages (figure 2) through a regular monitoring of athletes symptoms (pain score) and the score of impairment level linked to each sports category. A study conducted by Horobeanu et al[60] reported that periodic monitoring and early identification of symptomatic OSD, with basic clinical tests, appear to alert the medical staff about potential acute onsets. Subsequent recommendations to reduce training load resulted in low training days lost due to OSD. Progressing and regressing from one stage of irritability to the next is based on the improvement or worsening of both symptoms and functional impairment.

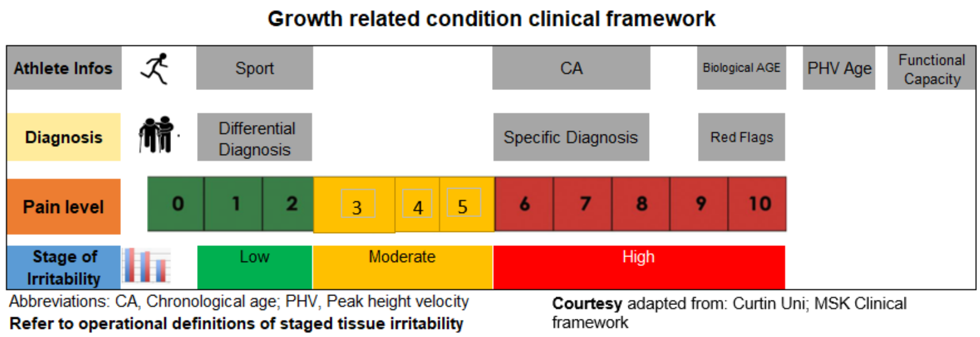
The bodily changes of adolescents during their growth-maturity journey will impact their psyche and consequently their coping skills during injury period and influence their rehabilitation duration and outcome. Ardern et al[61] found that psychological readiness to return to sport and recreation was the factor most strongly associated with returning to the preinjury activity. The psychological element of athletes is overlooked as a determinant in injury occurrence and or rehabilitation outcome. The provision of a sport psychologist is crucial to help youth athletes transitioning their pubertal periods.

CLINICAL IMPLICATIONS

Athlete profile: does the athlete present with characteristics of at-risk athletes?

After identifying injury risk factors, a series of assessments can be undertaken to investigate whether an individual demonstrates the characteristics of an athlete who is more susceptible to injuries with reference to many research studies findings. Efforts should also be undertaken to aggregate baseline information and screenings data, sporting demands and clinical presentation to yield a definite and appropriate clinical working diagnosis considering pathoanatomic diagnosis and tissue irritability.

Early warning symptoms (e.g. Complaints, limited performance, joint soreness) are an indication for prompt and personalized athlete care. In the meantime, practitioners can use compiled information to guide the athletes care and to manage future risk. (**Figure 2**) This may devise clinical practice evidence-based guidelines, rather than clinical judgement.



Legend: *CA, chronological age; PHV, peak height velocity (Courtesy Curtin University)*
Figure 2: *Growth-related injuries- clinical framework*

Unfortunately, there is little supporting evidence in the literature for the appropriate care of skeletal problems in children. Recommendations are mainly based on opinion and tradition, leaving great opportunities for future research and discovery in our active pediatric population.[37]

The actual practices related to youth injuries management and care are often based on inadequate evidence, errors in reasoning, oversimplification, and wide variations in beliefs.

This can find its explanation in the paucity of original research linking adolescent, sport participation and injuries, and the available research on soccer players has yielded inconclusive findings.[9,12,14,62,63] . The lack of high-quality, patient-oriented research in younger athlete populations and the absence of research on physeal injuries pose notable gaps in the literature. These gaps include minimal data establishing the incidence, prevalence, and severity of overuse injuries in youth athletes, especially with respect to physeal involvement.[64]

The principle that our medical intervention decisions are based on sound data rather than anecdote is a compelling and appropriate expectation that our youth athletes await.

However, it is rare to consistently embrace this approach in our daily patient practices as contemporary views in sports medicine and injury prevention suggest that sports injuries are 'complex' phenomena.[65] Prevention is better than cure.

It is possible to prevent sports injuries.[65] Injury prevention strategies to reduce the risk of overuse injuries in adolescents, such as tracking training load, training volume, ensuring appropriate biomechanics, sufficient rehabilitation post injury and education and communication to players and coaches regarding the negative effects of playing through injuries are required.[66,67]

A new paradigm, bio-banding, for youth training was suggested to substitute the conventional reference to previous grouping of athletes based on chronological age to deliver and plan training sessions. Bio-banding refers to the grouping of youth athletes within a given CA range into 'bands' or groups based on estimated biological maturity status for specific competitions and/or training. Percentage of predicted adult height attained at the time of observation is the maturity indicator presently used in bio-banding. It is a recent application and extension of the concept of 'maturity matching'.[68] The project is in its infancy and aims to address individual differences in biological maturation among participants in youth sports.[69] It attempts to group youth athletes within a specific chronological age range on the basis of maturity status. This could have enormous implications on injury development among at risk groups of youth athletes (early and late mature). According to Cumming[32], the bio-banding initiative was founded upon an awareness that later maturation and/or smaller size presented a temporary disadvantage in soccer, and that such bio-banding afforded more opportunity to demonstrate and apply their technical, tactical, and physical attributes. This concept could be extended to other sports such as track and field events and racket sports. In our training center, late mature athletes, from development groups and their normal and early peers were provided respective and specific training matching their maturity status. . However, the adoption of such ambitious initiative at a larger scale will depend on the willingness of sporting governing bodies and decision makers.

Strengths and limitations of this project

The lack of high-quality, research in young non-soccer athlete populations and the absence of research on immature skeletal injuries pose notable gaps in the literature. To our knowledge, this is the first project performed on injury and injury risk on Middle Eastern multi-sport youth elite athletes. All studies of this project were prospective, cohort design and represent the singularity of our population where all available participants were enrolled with no selection bias. All studies used comprehensive and a reliable injury surveillance system, standardized repeated measurements, consistent data collection and appropriate statistical approaches.

Bahr et al.[70] recommended that the preferred study design for risk factor analyses is a prospective cohort study, where the different candidate risk factors can be measured at baseline and the cohort followed prospectively to record injuries in a defined period of time. Studies of prospective, and cohort design minimize the occurrence of errors associated with recall, which is a problem with retrospective study designs.

In respect of an academy environment, our population has full access to full-time employed clinicians who are solely responsible for the handling of the injury surveillance system and ensured consistency in data collection. However, sample size within multisport sub-groups, included in the studies is small and inhomogeneous. This represents a limitation of this thesis. It is also worth mentioning that we did not analyse differences between athletic disciplines in the frequency and characteristics of injuries among enrolled athletes sub-groups in our chapter two study I.

'All complaints" injury definition regardless of injury burden was used. Athletes and coaches are encouraged to report the complaints to an assigned physiotherapist. Conversely, other studies[23,28] used web-based surveys to collate data related sports injuries.

A limitation to this approach is that the success of the system depends on the willingness of athletes to respond to the questionnaires. These are surveillance studies without assessment by a medical professional. It was also noted that sometimes parents completed the data, due to the young age of the players. Even though the method has been validated for elite adult athletes, it has not been validated in such a young population where the parental involvement in the questionnaires was significant.

Little is known about the effects of population-specific risk factors, like growth-related changes and training volume, on the development of injuries in skeletally immature individuals.[71] Therefore, studies should establish a clear definition of youth injuries in sport and determine the mechanisms and risk factors associated with their development.

Our data suggest (chapter three part one) that adolescent athletes might be scouted with a preference for youth with advanced maturity. The diverse sample sizes based on the classification group and the three maturity groups (late mature, normal mature, early mature) derived from the repeated data collected must be considered a limitation because direct comparisons are difficult as sample size is small. Small population sample in our dataset (chapter three part two) had less power to assess any relationship between injury type and maturity level clearly.

Relatively little research has been designed to determine the effectiveness of injury prevention measures in children's and youth sports. [72]

Only a few modifiable injury risk factors have been statistically evaluated and interventions have often been overlooked. Psychological variables such adolescent personality trait, vulnerability and coping skills as intrinsic risk factor predisposing the athlete to injury should be considered for injury prevention programmes.[73,74] As injury causation is multifactorial, it follows that injury prevention programmes should target each of the multiple causes.

Recommendation-Future research

The investigations performed in this doctoral thesis were uniquely limited to personal biological factors (e.g. CA, SA, maturation, hyperlaxity) and external risk factors (e.g. exposure, training load). This is leaving a gap in the understanding of the interaction between the multiple multifaceted risk factors and the complexity of injury occurrence. Therefore, future research studies are needed, and should focus on other aspects of adolescent athletes such as social and psychological factors which may offer a broader view to injury risk. Our relatively short- term presented study results require further qualification and more research is required to establish whether there are thresholds of training, and or whether increased training load increases the likelihood of injury and also to determine our population training load, ACWR "sweet-spot" as recommended by Gabbett[75] and in light of our preliminary results from our in-house pilot study.

Given that the interpretation and comparison of findings among our studies is restricted by small samples and heterogenous sports events, it is useful to conduct studies on youth for longer periods with appropriate sample sizes and more homogenous cohorts.

As our study on GJL in adolescent athlete showed that the Beighton scores lessened sharply at the age 14, a study on GJL and its correlation with injury in selected age groups is recommended to explore and draw conclusions about potential effect of hormonal changes, flexibility and puberty affecting joint mobility.

Epidemiologic data have been used to develop injury prevention programs in order to reduce injury risk. Randomized controlled trials (RCTs) are warranted to investigate the effect of potential interventions on injury incidence. The effectiveness of injury prevention measures should be explored, but more importantly potential intervention programmes must ensure an uptake of the interventions in a real-world context as recommended in the Translating Research into Injury Prevention Practice (TRIPP) framework by Finch.[76]

Summary- Advice for clinical practice

We recommend physiotherapists involved with adolescent athletes to be cognizant of the range of modifiable and non-modifiable risk factors specific to youth athletes. It is important to recognize the unique characteristics of adolescent growth and development that have implications for the injuries. Clinicians should be an active part of a cohesive multidisciplinary (i.e. physiologist, biomechanist, and coaches) team and at the center of a shared decision-making process.

Biological age and other markers of maturation status (SA, pre-circa and post PHV, expected mature height and percentage of attained mature height) collated through repeated measurement and, when feasible, using both invasive (Fels method) and non-invasive (anthropometric measurements) methods should be envisaged. A synthesis of seasonal screenings should be carefully considered followed by subsequent athletes profiling.

Overuse injuries are highly prevalent among youth athletes. To capture this, "all complaints" injury definition should be instituted in the injury surveillance system regardless of the incurred injury burden.

Take Home Messages

Late maturity level is associated with the odds of growth-related injuries (osteochondrosis) and gradient of attained mature height is also associated with heightened injury risk.

Hypermobile youth athletes engaged in contact sports (i.e. team sports, combat sports) are also at heightened risk of sports injury. The Beighton scores lessen significantly at selected age group 13-15 years old. Such findings are in agreement with previous studies and might pertain to hormonal changes during male adolescent and or inflexibility within pubertal phase. Contrary to old belief linking joint laxity with injury, our study revealed an association between Beighton score 0-3 with sprain injury type.

Early identification of at-risk population and intervention are a particularly relevant approach to reducing the impact of overuse injuries in certain groups of athletes (e.g. late mature).

The clinical framework based on tissue irritability concept[59] (**Figure 2**), summarizes key elements of clinical reasoning for a sound and evidence- based approach to manage and layout guidelines for growth-related conditions (osteochondrosis). Physiotherapists' clinical judgment will always remain a cornerstone of athletes' care, but medical decisions must be anchored by rigorous scientific evidence rather than opinion-based or expert consensus.

What is already known?
▶ There is a paucity of epidemiological data on the extent and determinants of injury in highly trained adolescents in respect to an academy environment ▶ Adolescent athletes are on a journey to adulthood and their development should be seen always as a long-term project
What this dissertation might add?
▶ Maturation status might be an established intrinsic risk factor of highly trained adolescent. Early mature athletes are at heightened risk of injury. Adolescent maturing at later age are at risk of osteochondrosis ▶ Healthcare providers working with adolescent athletes should be cognizant about critical periods of growth and maturation which influence injury rate in several sports ▶ Preseason screening for generalized joint laxity (GJL) is recommended as gradient Beighton scoring and contact sports both influence injury risk

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Chapter Seven

SUMMARY

NEDERLANDSTALIGE SAMEVATTING (SUMMARY IN DUTCH)

SUMMARY

Youth sports participation promoted for its multifaceted benefits entrenched an eminent risk of overuse injury. Growth-related conditions represent one type of overuse injury exclusive to adolescents' athletes. These are often engendered injuries by growth-related changes, training volume, and other risk factors superimposed on skeletally immature individuals. There is a paucity of high-quality research on specific risk factors for growth-related injuries in younger athlete populations in the literature. The burden associated with adolescent sports injuries is substantial. This thesis aimed to establish the incidence, prevalence, and injury characteristics in youth athletes, and highlight the effects of growth-related changes, hypermobility and training volume on the development of injury risk.

In chapter one, an introduction of the context, content and aim of this thesis is given. In addition, the paradox of sports participation for youth athletes, definition of certain operational terms, the immature skeleton and the reason for concern, and the growth-imposed changes underpinning the development of youth injuries were introduced. The academy environment, its mission and vision as long-term athlete development and its particular talent identification program was highlighted. The singularity of the population, adolescent and Middle Eastern enrolled in the different studies was also reported.

In chapter two, we examined the incidence and pattern of injuries in young elite multi-sport athletes. A high incidence of injuries with a prevalence of overuse injuries was found in this youth population. Overuse injuries are a common cause of premature retirement from sports and may be symptomatic long after sporting careers are finished. This is a compelling reason why a closer look at injury inciting factors and prevention plans for youth athletes are needed.

In chapter three part one, we explored the effect of youth population-specific risk factors, like growth and maturation on the development of injuries. The study findings showed that maturity status plus percentage of attained predicted mature height are associated with injury in individual sports and racquet sports. It was also found that athletes maturing at an early age are more prone to injury compared to their peers. In respect to our academy environment, athletes who are advanced in maturity, are advantaged in the selection process.

In chapter three part one, a prospective observational study was carried out to relate injury characteristics to maturation level and revealed that athletes maturing at an older age are at greater risk of osteochondroses. We proposed an operational clinical framework

to guide practitioners in continuously managing injury risk whilst considering factors unique to the athlete's sport, biological age, site of injury and differential diagnosis. Early diagnosis is a particularly relevant approach to reducing the impact of overuse injuries in certain groups of athletes (i.e. late mature). This will help devise evidence- based clinical guidelines rather than solely clinician own judgement and expert opinion.

Generalized joint laxity, benign feature present in some children and adolescents and quantified by gradient Beighton scoring system (from 0-9) is found to be a hindrance rather than a help, especially when the athlete is engaged in contact sports according to our cohort prospective study in **chapter four**.

Osteochondroses requires careful apophyseal-physeal, athlete load monitoring (i.e. optimal loading and training load dose response) to mitigate eminent long- term consequences.

In **chapter five** a pilot study was carried out to refine the methodology for a larger scale investigation on apophyseal injuries as part of a research project at the academy sports department aiming to investigate youth, sports participation and optimal loading. An approach to training load is important to provide greater insight to training stress.

In c**hapter six** we reflected on the main findings of this thesis, and the practical implications to yield a clinical framework. Understanding the development of youth injuries, as a complex interaction between population-specific modifiable and non-modifiable risk factors, will help us guide our management and to improve our prevention efforts. In fact, the contribution of certain variables to the etiology of injury (as determined from reductionist approaches) may be drastically influenced by the multifaceted, non-linear interactions.

In our studies we identified at risk prone population, yet we should admit that sports injuries and injury prevention are an intricate phenomenon and more studies on complex approaches should be promoted.

Nederlandstalige SAMENVATTING

Jeugdsportparticipatie wordt wereldwijd gepromoot vanwege zijn veelzijdige gezondheidsvoordelen, maar anderzijds verhoogt dit het risico op een (overbelastings)letsel. Bij kinderen in de groeispurt worden vaak groei-gerelateerde aandoeningen aangetroffen. Deze letsels zijn vaak het gevolg van een hoge (eenzijdige) belasting op structuren die een snelle groei doormaken.

Ondanks de hoge frequente van deze groei-gerelateerde letsels, blijkt er heel weinig hoogwaardig onderzoek i.v.m. specifieke risicofactoren te bestaan. De impact van deze letsels bij de populatie van jonge adolescenten is echter aanzienlijk. Dit proefschrift heeft tot doel de incidentie en prevalentie van groei-gerelateerde letsels bij jeugdatleten te bepalen, en de rol van hypermobiliteit en trainingsvolume op de ontwikkeling van deze letsels te onderzoeken.

In **Hoofdstuk I** wordt een inleiding gegeven over de context, inhoud en doelstelling van dit proefschrift. Daarnaast wordt de paradox van sportparticipatie voor jeugdatleten beschreven. Tevens wordt de definitie van bepaalde operationele voorwaarden beschreven, evenals een beschrijving van het onvolwassen skelet en de reden tot bezorgdheid m.b.t. groeistoornissen. Tot slot worden de groeiveranderingen die ten grondslag liggen aan de ontwikkeling van de groei-gerelateerde letsels besproken. De topsportschoolomgeving, haar missie en visie als langdurige atleetontwikkeling en haar specifieke talentidentificatieprogramma worden benadrukt.

In **Hoofdstuk II** wordt de incidentie en het type van letsels bij jonge topsporters onderzocht. Vastgesteld werd dat een hoog aantal van de opgelopen letsels in deze jeugdpopulatie overbelastingsletsels zijn. Deze overbelastingsletsels zijn een vaak voorkomende oorzaak van vroegtijdig stoppen met sporten en kunnen symptomatisch zijn lang nadat de sportieve carrière is afgelopen.

In **Hoofdstuk III, deel I,** hebben we het effect onderzocht van bepaalde risicofactoren zoals groei op het ontstaan van blessures bij een jeugdige topsportpopulatie. De resultaten laten zien dat de maturiteitsstatus en het bereikte percentage van de voorspelde volwassen lengte geassocieerd zijn met letsels bij individuele sporten en racketsporten. Ook werd vastgesteld dat atleten die op jonge leeftijd volwassen worden, meer vatbaar zijn voor letsels dan hun leeftijdsgenoten. Met betrekking tot onze topsportschoolomgeving, hebben atleten die ver gevorderd zijn in volwassenheid, een voordeel in het selectieproces.

In **Hoofdstuk III, deel II,** werd een prospectieve observationele studie uitgevoerd om de kenmerken van de letsels te relateren aan het maturiteitsniveau. Hieruit bleek dat atleten die op latere leeftijd volwassen worden een groter risico lopen op osteochondrose. We stelden een operationeel klinisch kader voor om sporters te begeleiden bij het continu beheren van letselrisico, rekening houdend met factoren die uniek zijn voor de sport, de biologische leeftijd, de lokalisatie van het letsel en de differentiële diagnose.

Gegeneraliseerde gewrichtslaxiteit, ,gekwantificeerd door het Beighton scoringssysteem (van 0-9), blijkt een risicofactor te zijn voor het ontstaan van letsels bij de jeugdsporter in het geval de sporter participeert in een contactsport. Deze bevindingen werden bekomen in onze prospectieve cohortstudie beschreven in **hoofdstuk IV**.

In **Hoofdstuk V** is een pilotstudie uitgevoerd om de methodologie te verfijnen voor een breder onderzoek naar apofysaire letsels bij jonge adolescenten in een topsportschool. Dit onderzoek moet leiden tot verbeterde inzichten en richtlijnen m.b.t. jeugd, sportparticipatie en optimale belasting. Een beter inzicht hierin is belangrijk om meer inzicht te verkrijgen in trainingsstress.

In **Hoofdstuk VI** hebben we de belangrijkste bevindingen van dit proefschrift besproken en de praktische implicaties voor een klinisch kader. Inzicht in de ontwikkeling van sportletsels, als een complexe interactie tussen populatie-specifieke risicofactoren zoals trainingsbelasting en -volume en factoren als groei, maturatie en hypermobiliteit, zal ons helpen om onze preventie-inspanningen te verbeteren. In onze studies identificeerden we een risicogevoelige populatie, maar we moeten toegeven dat het ontstaan van sportblessures een complex proces is, waardoor letselpreventie niet eenvoudig is.

Appendices

ACKNOWLEDGEMENTS

CURRICULUM VITAE

PHD PORTFOLIO SUMMARY

LIST OF PUBLICATIONS

ACKNOWLEDGEMENTS

After an intensive period of five years, today is the day: writing this note of thanks is the finishing touch on my thesis.

It has been a period of intense learning for me, not only in the scientific arena, but also on a personal level. Writing this thesis has had a big impact on me.

I would like to reflect on the people who have supported and helped me so much throughout this period

I am grateful to all of those with whom I have had the pleasure to work during this and other related projects. A word of appreciation and love goes to Aspire academy for sports for its inspiring spirit that instilled me and all students' athletes in different generations.

Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my loved ones; whose love and guidance are with me in whatever I pursue. Most importantly, I wish to thank my loving and supportive wife, Mounira, and my three wonderful man and women, Amine, Meriam and Yosra, who provide unending inspiration.

This work would not have been possible without the full support of my promoter professor Erik Witvrouw. I have been extremely lucky to have a supervisor who cared so much about my work, and who responded to my questions and queries so promptly.

Each of the members of my thesis Committee has provided me extensive personal and professional guidance and taught me a great deal about both scientific research and life in general. I would especially like to thank Dr. Amanda, member of the committee and lead at Aspetar hospital with her we shared so many years of work, her role in the inception of the topic is crucial and her guidance is very tangible.

CURRICULUM VITAE

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PROFESSIONAL PROFILE

Graduated from the University of Centre, College Medicine SOUSSE TUNISIA Physiotherapy program.

Since completing my training as Physiotherapist, I have been working as a clinician in different settings of tertiary hospitals OPD and in-patients.

The caseload that included mostly Orthopedics and Trauma and Specific surgery including ACL and HIP surgery.

Then I moved to the promising field of Sports Medicine. Sports Medicine Center, under QNOC, the FIFA accredited Orthopedic hospital ASPETAR. I am privileged to be a member of multi-disciplinary, multinational and culturally diverse medical community (+54 nationalities). Aspetar remains the gem of sports health care provider in the MENA and worldwide.

At Aspetar, I have gone through sports medicine topics one by one and acquired development by the best and renowned talents in the field.

Fortunate to complete a certificate in Osteopathy funded by the QNOC Qatar 2006.

CAREER SUMMARY

Jan 2003: Appointed then as Football 1st team Physiotherapist in the Stars League (QSL) with prominent and notorious players.

Oct 2005: Hired in the stunning Sports Excellence Academy ASPIRE.

My focus was then for adolescent athletes and their peculiarities management. Investigation of the intriguingly causes of youth injuries, started with reductionist theory of singular risk factor and looking into injury pattern, modelling and recursive loop.

MY ASPIRE PARCOURS

An outstanding and state-of-the art setting dedicated to transform adolescent into world and loco-regional champions and societal leaders.

ASPIRE is now a renowned innovative Academy, known for its stunning facility and state-of-the art and where scientific a contribution from world-class expert is combined with field technical training "from bench to trench".

At Aspire I, with a bunch of well-motivated colleagues from all over the world, conceived and built processes, and guidelines from scratch. We teamed up, with the precious support from the management to optimize our delivery and to present our clinical work to the rest of the world in worldwide held international conferences.

Dec 2013: Meanwhile, my research penchant led to accomplishing MSc with Merit in Clinical RESEARCH from the prestigious UK University of Liverpool (UK UoL).

Nov 2015: Combing clinical practice with research incited me to pursue with PhD at Ghent University BELGIUM where my promoter Prof. Erik W. and I investigated Youth and Injury, extent, risk factors and avenues of prevention.

Other personal interests at Public Speaking (TM-CC) within the supportive environment of Toastmasters international (TM Intl) and many other self- improvement fields as

→ Reading books
→ Paradigm Shift
→ NERTI, NLP, TED
→ Certified Handwriting

EDUCATION AND QUALIFICATIONS

→ Degree in Physiotherapy, Centre University, College of Medicine Sousse
→ MSc in Clinical Research University of Liverpool, UK 2013

COURSES AND WORKSHOPS ATTENDED

2013-2018

- → Statistics SPSS: Qatar University
- → Clinical reasoning
- → Ankle Examination Course

PROFESSIONAL MEMBERSHIPS AND POSITIONS

- → Member of European College of Sports Sciences (ECSS)
- → Licensed AHP Qatar Council Health Professions (QCHP)
- → Coordinator, in-house CPD Aspire Academy (NSMP-ASPETAR)
- →

PHD PORTFOLIO SUMMARY

PhD Training

(Inter)national conferences - attendance

Community Service and CEC	Qatar University	2016
European College of Sports Sciences (ECSS) Conference	Vienna Austria	2016
IOC World Conference Prevention of Injury and Illness in Sport	Monaco	2017
European College of Sports Sciences (ECSS) Conference	Dublin Ireland	2018
PhD Meeting Group	Aspetar-Qatar	2018
Lecture series	Weekly- Aspetar	2019
In-House Presentation	AASMC- Doha	2019
PhD student day	Ghent-Belgium	2015

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(Original research A1, EJSS Ranking Q2- IF: 2.57-2017)
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Rejeb A, Johnson A, Farooq A, et al. Sports injuries aligned to predicted mature height in highly trained Middle-Eastern youth athletes: a cohort study. BMJ Open 2019;9:e023284-e.
(Original research A1, BMJ Open Ranking Q1- IF: 2.42)
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Rejeb A, Fourchet F, Materne O, et al. Beighton scoring of joint laxity and injury incidence in Middle Eastern male youth athletes: a cohort study. BMJ Open Sport; Exercise Medicine 2019;5:e000482.
(Original research A2, BMJ Open SEM Ranking Q2- IF:1.51)
DOI:10.1136/bmjsem-2018-000482

Rejeb A, Johnson A, Horobeanu C, Vaeyens R, Witvrouw E. EPIDEMIOLOGY OF SPORTS INJURIES AMONG HIGHLY TRAINED YOUTH MULTISPORT ATHLETES. British Journal of Sports Medicine 2017;51:377.
(Abstract C3, BJSM JCR Q1- IF:5.025- 2016)
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(Original research A2, AsJSM Open Ranking Q3- IF: 1.4)
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Rejeb A, Johnson A, Farooq A, et al. Sports injuries aligned to predicted mature height in highly trained Middle-Eastern youth athletes: a cohort study. BMJ open 2019;9:e023284-e. Submitted: British Medical Journal (Open). 2019

Ishak A, Ahmad H, Wong J, **Rejeb A**, Hashim H, Pullinger S. Two Sets of Dynamic Stretching of the Lower Body Musculature Improves Linear Repeated-Sprint Performance in Team-Sports. Asian Journal of Sports Medicine 2019;In Press:1-9.
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Fourchet F, Materne O, **Rejeb A**, Horobeanu C, Farooq A. Pelvic tilt: reliability of measuring the standing position and range of motion in adolescent athletes; 2014.