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ORIGINAL ARTICLE

Title: Shedding Light on Incidence and Burden of Physeal Injuries in Youth Elite Football Academy: A 4-Season Prospective Study

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ABSTRACT

Introduction: Physeal injuries have been overlooked in epidemiological research in youth sports. Our prospective study investigated the incidence, severity, and burden of physeal injuries in a youth elite football academy.

Methods: 551 youth male football players from Under-9 to Under-19 were included and observed over four consecutive seasons. Injuries involving the physis were diagnosed and recorded according to type, location, and diagnosis. Injury incidence (II), severity (days lost), and injury burden (IB) were calculated per squad per season (25 players/squad).

Results: There were 307 physeal injuries: 262 apophyseal- (85%), 26 physeal- (9%), 2 epiphyseal- (1%) and 17 other physeal-injuries (5%) with 80% (n=245) causing time-loss. The overall mean incidence of time-loss physeal injuries was 6 injuries/squad-season leading to a total of 157 days lost/squad-season. The U-16s had the highest burden with 444 days lost per squad-season [Median: 20 (95%CI:12-30) days; II: 10 (95%CI:7.3.1-13.4)]. Apophyseal injuries of the hip-pelvis resulted in the greatest burden [Median: 13 (95%CI: 10-17); II: 2.5 (95%CI: 2.1-3.0)]. Peak apophyseal injury incidence per body parts occurred in U-11 for foot-ankle (II: 2.4; 95% CI: 1.0-4.9), U-14 for knee (II: 4.5; 95% CI: 2.7-7.1), and in U-17 for hip-pelvis (II: 6.4; 95% CI: 4.2-9.3).

Conclusion: Physeal injuries accounted for a quarter of all-time loss with the largest injury burden in U-16. Most physeal injuries involved the lower limb and affected the apophysis. Physeal and apophyseal injuries incidence, burden and pattern vary substantially depending on age. Hip-pelvic apophyseal injuries accounted for the largest injury burden.

KEYWORDS

Soccer, Pediatric, Avulsion, Osteochondroses, Epidemiology, growth plate, Hip-pelvis apophysis, Physis

INTRODUCTION

Having an open physis is the most significant musculoskeletal tissue difference between the growing immature and the mature-adult skeleton.[1] Growing bone is less resilient than mature bone and can be overstressed and damaged by acute trauma, repetitive micro-trauma or a mixture of both mechanisms.[1] The pattern of musculoskeletal injuries in young athletes different from adults.[1] Physeal injury outcomes, treated either conservatively or surgically are generally excellent.[2] Misdiagnosis or mismanagement can lead to persistent symptoms delaying return to play, premature growth plate arrest, limited performance or even result in permanent sports limitations.[1-4] Regrettably, in elite youth football, despite over 40 years of research, detailed epidemiological studies on the recognition and distribution of physeal injuries are lacking.[4-6] Epidemiological research has mainly focused on acute injuries and most studies did not describe specific physeal injuries or classified them under general categories such as “fracture”, “bone”, or “overuse” injuries, impeding a clear representation of the situation.[7-9] In emergency paediatric medicine, physeal fractures account for 15% to 30% of all skeletal injuries in children.[1,2] In football, physeal fractures has been specifically reported only once, by Andreasen et al. (1992),[10] revealing a prevalence of 6% of all severe injuries during a youth tournament. With regard to osteochondrosis, several authors have broadly reported the overall prevalence of such diseases as being between 4.5% and 14%, reporting predominantly Osgood-Schlatter’s and Sever’s disease.[11-17] Recently, growth-plate injuries were observed to be the second most prevalent time-loss injuries and 50% of all fractures involved the physis.[18] As the incidence and burden of specific physeal injuries in youth elite football are unknown, detailed prospective studies are essential.[6,18] The primary aim of this 4-year prospective clinical study, was to examine the types, incidence and burden, of all physeal injuries occurring across different age groups, in an elite youth football academy. The secondary aim was to explore age related details of the apophyseal injuries.

METHODS

Study design and participants

A prospective cohort study in elite male youth football players was performed during four consecutive seasons (from August 2012 to June 2016) at the national training centre ASPIRE Academy in Doha, Qatar. A total of 551 players from 11 different age groups (under-9 (U-9) to U-19) were included. The U-9 to U-12 age groups trained/competed for an average of 9 h/wk over a period of 10 months per season. This typically comprised around 5 football training sessions including agility and coordination, and 1 domestic game per week. In addition, they participated in a 1-day tournament monthly. The U-13 to U-19 age groups trained for approximately 14 h/wk over a period of 10 months. This weekly load typically comprised 6–8 football training sessions, 1 strength training session, 1–2 conditioning sessions, and 1 domestic game. In addition, the players played with the academy in 2 invited international games every 3 wks. Written informed consent to use the collected injury data for research purposes was sought and obtained from the player's guardians. The study was designed according to the requirements of the Declaration of Helsinki and approved by the scientific boards of ASPETAR and ASPIRE Academy. Ethical approval was granted by the Anti-Doping Lab Qatar Institutional Review Board (IRB Application #E202012018).

Data collection and injury definition

All musculoskeletal injuries sustained were prospectively recorded by each squad's assigned physiotherapist in an electronic standardised format based on the consensus of Fuller et al.[19] Each physiotherapist submitted their discharge injury information on a weekly basis to the senior physiotherapist, who reviewed and consolidated all data. An injury was recorded as a result of any physical complaint resulting from a game or training that required a clinical examination. A visit to the medical department requiring a clinical examination without missing a full training session or game was defined as a "medical attention" (MA).[19] A visit resulting in a player being unable to fully take part in the training session or game the following day was defined as a "time-loss injury" (TLI). Only injuries of the physis sustained in the context of in football were included in this study. For complementary broader injury epidemiological information, please refer to published studies.[18,20] Player unavailability was calculated as the number of days (severity) missed from the date of injury (day zero) until the day before the return to training participation and game availability.

Physeal injuries

Physeal injuries are not explicitly considered by the Fuller et al.[19] consensus statement on injury definitions. Therefore, we adapted the injury surveillance by adding "growth-related injuries" and "physeal fracture" as specific injury types. More sub-categories were also integrated into the original body chart, itemizing the related apophysis and physis for each specific body-parts. As sub-types, the different types of diagnosis were also listed (e.g. avulsion, osteochondrosis, Salter-Harris I, II etc).[18]

History and clinical examination

The clinicians (sports physician and physiotherapist) asked each player for a clear explanation of the injury mechanism and symptoms, elucidating if the injury onset was acute/sudden, micro-repetitive/gradual or a combination of both. Clinicians also enquired whether similar pain had occurred prior to the injury. Regarding apophyseal symptoms and examination, pain at insertional points on palpation, passive movements and stretches and, active movements including resistance testing were positive findings (associated with muscular insertions) that were considered to classify the injury.[4,21,22] Differential clinical examination to rule out any muscle, tendon or other pathologies were similarly applied.[23]

Imaging investigation and diagnosis

When imaging was required (including bi-lateral comparison if needed), the reporting was performed by an experienced musculoskeletal radiologist. Positive imaging findings such as oedema, physeal widening, consistent with a traction type injury at the insertion were the signs considered. When clinical signs matched the radiology report, the diagnosis was made directly. In the case of negative image, the radiologist ruled out any adjacent muscle, tendon or other tissues injuries and the final diagnosis was made by the sports physician based on the history, clinical examinations, and rehabilitation outcomes.

Data analysis

Injury incidence was calculated as the number of MA and/or TLI per squad-season. A squad-season was based on a typical football team of 25 players.[24] Severity (time-loss) of injuries is presented either as mean ± standard deviation (SD) in the tables, or in cases of a skewed distribution as the median of days lost in the figures. Uncertainty for the point incidence and burden is presented as 95% confidence interval (95%CI) assuming a Poisson distribution.[25] Injury burden was calculated as: Mean incidence per type of injury × median time-loss per type of injury (days). Injury burden was expressed as the number of injury days lost per squad-season (95% CI).[24] Age at injury is presented by the median and interquartile range (25^{th}-75th percentiles) and SD values. A p-value <0.05 was considered the cut-off for statistical significance.

RESULTS

All physis injuries

During the 4-year study period (from 2012-13 to 2015-16), 2204 injuries were recorded in a cohort of 551 youth male football players (1091 player-season) from under U-9 to U-19 (Table 1). Of these, 307 injuries (14%) involved the physis. Eighty percent (n=245) of the physis injuries led to time-loss and resulted in 27% of the total lay-off, accounting for 19% of all time-loss injuries and for 30% of all severe injuries (>4 weeks).

-Insert Table 1 here-

The majority of the physeal injuries (90%) involved the lower limbs; 6% affected the upper limbs and 4% the spine (Figure 1). Physeal injuries mainly occurred during training (60%; n=183), with 39% (n=119) during games and 2% (n=5) in fitness/performance testing.

-Insert Figure 1 here-

There was an estimated overall mean incidence of 7 MA and TLI (95% CI, 6.3-7.9) per squad-season and 5.6 TLI (95% CI: 4.9-6.4) per squad-season accounting for a mean absence of 28±43 days per physis injury across all age groups (Table 2). Apophyseal (85%), physeal (9%), epiphyseal (1%) and others' physis injuries (6%) were the main types of physis injuries.

-Insert Table 2 here-

Of the 26 physeal fractures, 42% (n=11) were contact-trauma and 58% (n=15) were non-contact. Proximal tibial physeal fractures were the only lower limb physeal fractures that all were non-contact (n=4). The total number of days lost was 6862 days, resulting in an overall burden of 157 days lost per season (95% CI: 153.5-161.0 days) for a squad of 25 players. The incidence and severity for each age group is presented as a risk matrix in Figure 2. No recurrence of physeal injury occurred.

-Insert Figure 2 here-

The median age and interquartile range (25-75) of physeal injury occurrence was 14.7 years (13.1-15.7 yrs.). Age median and interquartile for each diagnosis are displayed by the figure 3. Distal tibial physis fracture occurred at a median age of 10.9 years (9.4-12.4 yrs.), while median age of the iliac crest apophyseal injuries was 15.5 years (15.4-16.4 yrs.).

-Insert Figure 3 here-

Lower limb apophyseal injuries

A total of 258 lower limb apophyseal injuries occurred, 60 (23%) were MA and 198 (77%) were TLI. 3.5% were re-injuries. Lower limb apophyseal TLI had the highest incidence 4.5 (95% CI: 3.9-5.2) and were the most burdensome in the study (86 days/squad-season; 95% CI: 83-89 days; 55% of all physeal TLI). Apophyseal injuries of the hip-pelvis were the most prevalent (56%) and most burdensome (45 days/squad-season; 95% CI: 43-47 days) from the lower limb (Figure 4). Significant lower limb apophyseal TLI incidence between age groups was observed (Figure 5): the peak incidence of foot-ankle apophyseal injuries occurred in U-11 (2.4; 95% CI: 1.0-4.9), knee in U-14 (4.5; 95% CI: 2.7-7.1) and hip-pelvis apophyseal in U-17 (6.4; 95% CI: 4.2-9.3). Sever's disease was the most common diagnosis (79%) of the foot-ankle apophyseal injuries and Osgood-Schlatter (78%) for the knee. The anterior inferior iliac spine (AIIS; 39%), os pubis (23%), lesser trochanter (15%) and anterior superior iliac spine (ASIS; 13%) were the most prevalent hip-pelvis apophyseal injuries. The risk matrix for all lower limb apophyseal injuries (Figure 6) displays the burden for each apophyseal diagnosis depicted by osteochondrosis (91%, n=180) and avulsion (9%, n=18).

-Insert Figure 4 here-

-Insert Figure 5 here-

-Insert Figure 6 here-

DISCUSSION

This is the first large scale prospective study investigating physeal injuries in a wide range of age groups in an elite youth football academy. In this cohort, physeal injuries occurred across all the age groups with an overall mean incidence of 6 time-loss injuries per squad-season. A squad of 25 players lost an average of 157 days per season due to physeal injuries. The highest injury burden was in the U-16s, where 444 days were lost each season. The vast majority of physeal injuries affect the lower limb and most often the apophyses. Physeal and apophyseal injury incidence, burden and pattern vary substantially by age group. Hip and pelvic apophyseal injuries accounted for the largest injury burden.

Total physeal injury prevalence and incidence

Physeal injuries accounted for 14% of all medical attention and injuries,[18] 19% of all time-loss and 30% of all severe injuries (>4 weeks). The majority affected the apophysis and 90% were in the lower limb. Injuries of the physis, epiphysis and the other physis injuries were the other categories of injury. In football academies, the overall prevalence of time-loss growth-related injuries has previously been quantified between 4.5% to 14% giving an incidence per squad-season ranging from 0.4 to 4.7 injuries.[11-13,15,16] Direct comparisons are difficult, as neither physis, epiphysis injuries nor diagnosis have been considered specifically.[9,15,16] The overall higher prevalence and injury incidence of physeal injuries in our study, compared to the existing literature, might highlight the bias due to not including these in previous injury surveillance systems.[8,19] It may also reflect the increase of youth football development intensification over the last decade and its association with a greater injury odds ratio and greater mechanical stress on the growth plate of the lower limbs.[26,27] Lastly, the unique specificity of our cohort of youth elite footballers from a Middle Eastern country, raises the potential impact of ethnicity on injury pattern.[28] The hip-pelvis was the most common body region affected by the physeal injuries accounting for 45% of all time-loss physeal injuries. With up to 42%, the knee has been habitually documented as the most prevalent body-part of osteochondral disorders.[11-14,29] However, in youth French players, 20% of all osteochondral disorders were located at the hip-pelvis, accounting for 21% of all hip-pelvis time-loss injuries.[11] The 30% prevalence of severe physeal injuries in our study is much higher than has been reported in Italian elite academies (11.5%), but lower than the 36% observed in French elite youth players. When considering comparable age groups with the French study (U-14 to U-16), there is a similar prevalence to our study (38%).[11,29]

Physeal injuries and age group burden

The highest burden of physeal injuries was found between U-13 and U-16 with a loss of 208 to 444 days per squad-season. No other published data are available for comparison, as only incidence and severity have been described.[11-13,15,16] However, these age groups have been identified as having the highest injury risk.[30] This burden of physeal injuries accounts for 33% to 49% of the total injury burden of these teams and therefore gives rise for concern of a detrimental impact on the players development and potential prevention strategies.[18] Close monitoring of growth and maturation, individualised training programs and football exposure management, seems to be a successful method to reduce the risk and consequently the burden of apophyseal and overuse injuries in these specific age groups in youth elite football.[20,31]

Physeal injuries and age median

A clear trend in the median age of the diagnosis of physeal and apophyseal injury occurrence by location was observed. Undoubtedly, this trend reflects the normal chronological sequence of the physeal endochondral ossification from cartilage to complete bony fusion.[1,2] While there is a wide variability in the time frame between individuals, the ossification process of the different physis and apophysis of the lower limb occur from distal to proximal.[1,32] The calcaneal secondary ossification centre may appear from 7 years of age, while fusion is normally completed between the ages of 15 and 18 years.[1,32] The iliac crest or pubic secondary ossification centres appear at approximately 15 years and the fusion may be delayed until 25 years of age.[1] The wider interquartile range between some physeal and apophyseal injuries might reveal a large discrepancy of maturation level between injured players. Regardless of all pathogenic factors that have been reported,[33] the biological development sequence of the different physis and apophysis remains essential knowledge for understanding risk factors and having good clinical awareness.

Lower limb apophyseal injuries

The high prevalence of apophyseal injuries (84%) in this cohort may emerge from the consideration of the non-time-loss injuries that other studies did not include in their methodology and, consequently, not reflecting the real extent of these disorders which are an early sign of overload.[11,34] Medical attention (23%) may appear irrelevant for the scientific literature, but they often require a lot of monitoring and clinical management to avoid symptom aggravation and prevent the player from time-loss football development. Reporting mild apophysis symptoms is essential and should not be considered as over-medicalisation nor as over-reporting.[24] Previous osteochondrosis is recognised as a risk factor for subsequent osteochondrosis in another unfused apophysis, suggesting a probable genetic component behind an abnormal response of the endochondral ossification to certain mechanical stresses.[33,35] Osteochondrosis is a common idiopathic condition of the immature skeleton, and not reporting a mild episode will not probably signal a player at potential risk. Hypothetically this could reduce the chance to prevent a more severe episode of the same, contra-lateral or even, another unfused apophysis at an older age.[33]

Incidence and burden

The hip-pelvis was the region with the greatest apophyseal injury burden compared to the knee and the foot-ankle. There is no other published work with which to make any comparisons. However, in young competitive footballers, knee overuse injuries were reported as having the highest burden.[7] While the data was not expressed in the same format, the results in elite French youth footballers are similar to our findings.[11] The incidence of different apophyseal injuries varies substantially depending on location and age groups. The peak incidence of foot-ankle time-loss apophyseal injuries (e.g. Sever's disease) occurred in U-11 and in U-14 for the knee (e.g. Osgood-Schlatter's disease) which is similar to what has been previously reported in the literature, except in English premiership academies where there is trend of peak of Osgood-Schlatter occuring in U-13.[11-13,17,29] The greatest incidence of hip-pelvic apophyseal injuries per squad season was found in U-17, which differs from Le Gall et al.[11] who reported the highest occurrence in U-14. The different age group considerations between both studies might explain this discrepancy. The incidence distribution of the apophyseal injuries locations by age-groups reflects the maturation process as early discussed and may highlight fragile period of endochondral ossification of the corresponding apophysis more vulnerable.[2,20,21] Recently, Materne et al.[20] emphasized that while players who were skeletally mature at the wrist had the lowest risk of lower extremity apophyseal injuries, they were still vulnerable for hip and pelvis apophyseal injuries. This emphasizes the need for clinical consideration of the sequential maturation process of the lower limb (distal to proximal).

Type and location

In our study, apophyseal injuries were considered as either osteochondrosis or avulsions. Avulsions required a greater recovery time compared with the osteochondrosis and the AIIS was the most frequently avulsed apophysis in our study, as also stated in a recent review.[36] While avulsion injuries are not systematically reported in youth football epidemiology,[12,13] a larger proportion of avulsion injuries compared with our results has been observed.[11] Iliac crest avulsions are uncommon,[37] however, it was the most severe apophyseal injury along with the avulsion of the 5th metatarsal in our cohort. The median severity of all apophysis osteochondrosis were similar, except for Kholer disease. Osgood-Schlatter's disease was the most prevalent osteochondrosis (28%), following by the AIIS (17%), pubic (14%) and Sever's disease (11%). Osgood-

Schlatter's and Sever's diseases have been usually identified as the most frequent osteochondroses in youth football and involved in 64% of all non-acute bone stress injuries.[11,12,14,17] Osgood-Schlatter's was a principal cause of all severe knee injuries in youth football but reported rates and burden vary depending age groups.[12,13,17,18] An Italian academy reported twice as many cases (44%) as the 21% observed in English premiership academies.[17,29] The high injury incidence and prevalence of the AIIS injuries is different from Le Gall et al.[11] who found the ischium as second most prevalent injured apophysis. It is not surprising that the AIIS is so frequent, as it's the proximal origin of the straight head of the rectus femoris, which is an important muscle in football movement specificity.[37] Pelvic and pubic apophyseal injuries have been widely ignored as a possible differential diagnosis of groin pain in adolescent and young adults and also have been misdiagnosed as muscle injuries in previous studies.[8,22,38]

Physeal fractures

Physeal fractures had an incidence of 0.6 injuries with a burden of 31 days per squad-season, accounting for 12% of all severe injuries. Similar to the literature,[2,3] Salter-Harris type I and II were the most common physeal fractures in our cohort. Physeal fractures occurred between the median age of 11.2 years (distal tibial physis) to 15.4 years (proximal tibial physis). Similar to the work by Peterson et al.,[39] half of the physeal fractures were located at the upper-limb (distal-forearm, hand/finger), occurring at a median age of 14.5 years. Physeal fractures are recognized to account for between 15% to 30% of all skeletal injuries, occurring between the ages of 10 and 16 years.[1,2,39] In team sports, epidemiological datasets on physeal fracture remain scarce.[6] In a football tournament, physeal fractures were found to account for 6% of all severe injuries and 30% of all fractures, with the majority located in the distal-upper-extremity.[10] The higher prevalence (50%) found in our study may be due to the consideration of a specific sports cohort (football),[18] which is different from most previous studies, considering different contact and non-contact team sports, individual sports or emergency pediatric environment.[1,2,6] In academies, ankle physis injuries have been reported for 0.1% of all ankle injuries, which is very low compared with the 1.4% found in our study.[40] Ankle sprains may have been over diagnosed by not ruling out physeal fracture in immature players.[4] As observed previously,[39] distal physis (61%) were more frequently injured than the proximal physis. Although for the lower leg this was not the case in our study where the proximal tibial was injured twice as often as the distal tibia. The proximal tibial epiphysis is recognised as a "pressure epiphysis" expose to compressive forces, particularly in kicking sports.[6] All proximal tibial physeal fractures in our study were non-contact, resulting from excessive repetitive stress, which is in keeping with previous literature.[6]

Football is generally recognised as an osteogenic sport; associated with positive effects on bone mass and strength of the weight-bearing bones.[41] However, current research on osteogenic effects in youth sports have not yet quantified the correct combination of specific characteristics such intensity, frequency, duration, non-repetitive movements, and rest towards optimal bone adaptation.[42] Lastly, the prevalence of spondylolysis was 4%, near to the 6% reported elsewhere.[43] The spondylolysis occurred at the median age of 15 years old (IQ: 14.5-15.6yrs.) and was the most burdensome diagnosis in this study (31 days lost/squad-season), representing 20% of the total time-loss of all physeal injuries.

Study Limitations

One limitation of our study is that individual exposure time is missing and therefore the incidence of injury in relation to exposure is not presented. To address this concern, as suggested by the latest International Olympic Committee (IOC) consensus statement,[24] the incidence of injury has been expressed per number of players per period of the sports specificity (squad-season). Calculating in this way facilitates clinical and practical interpretation. Nevertheless, the absence of individual exposure will not allow the reader to compare the data of the present study to other research expressing the injury incidence as injuries per 1000h of exposure.[11] A second limitation is the use of a novel classification system. As there was no pre-existing system available at the time of the study commencement, the detailed diagnosis and dataset of all growth plate injuries was done according to our clinical experience. As the classification system was novel, it's reproducibility is unknown. However, our prospective injury surveillance outcome provides a more accurate and new consistent insight of injuries in youth elite football academy, certainly leading to a greater clinical and preventive contribution as recently recommended.[24]

PERSPECTIVES

Lack of specific attention and reporting on the true burden of physeal injuries in youth elite football has likely been underestimated until now. This first prospective investigation dedicated to physeal injuries in a youth elite football academy provides relevant clinical information for practitioners working in the field.

Physeal injuries account for a quarter of all time loss in youth football and mostly affect the lower limb. The incidence, burden, and location are chronological age specific. The highest physeal injury burden was found in the U-16 category. Osgood-Schlatter's disease is the most common apophyseal injury and hip-pelvic apophyseal injuries resulted in the largest injury burden with a peak of incidence in U-17. Spondylolysis was the most burdensome single diagnosis of all physeal injuries.

Clinicians should monitor early musculoskeletal complaints and be fully acquainted with the specificities of the immature skeleton pathologies to avoid potentials pitfalls and delays for the appropriate management of the condition. Physeal injuries require specific recognition in injury surveillance systems and data collection. This will allow to properly quantify their impact and permit progressing towards a greater evidence-based injury clinical examination, rehabilitation, and prevention in elite youth soccer players.

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TABLES

Table 1. Demographic characteristics of the players by age group (Displayed anthropometric values correspond with the measurements taken at the beginning of each season).

Age Groups	Total Players-Seasons	Age (years)	Stature (cm)	Trunk Height (cm)	Leg length (cm)	Body Mass (kg)	Body mass index
	N	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
U-9	**96**	8.7 ± 0.2	131.0 ± 5.3	69.9 ± 4.3	61.4 ± 3.6	26.5 ± 2.9	15.2 ± 1.4
U-10	**103**	9.7 ± 0.3	135.5 ± 6.5	71.6 ± 3.7	65.3 ± 4.6	31.0 ± 6.1	16.8 ± 2.1
U-11	**113**	10.7 ± 0.2	142.2 ± 6.6	74.4 ± 5.1	69.5 ± 1.8	36.0 ± 7.3	17.8 ± 2.7
U-12	**111**	11.6 ± 0.3	147.0 ± 6.6	76.5 ± 3.0	72.3 ± 5.4	39.2 ± 5.8	21.2 ± 19.8
U-13	**98**	12.7 ± 0.3	154.1 ± 7.0	79.0 ± 3.8	75.1 ± 4.2	43.2 ± 6.8	18.1 ± 1.8
U-14	**112**	13.7 ± 0.3	160.1 ± 7.1	82.8 ± 4.2	77.3 ± 3.9	48.1 ± 7.7	18.7 ± 1.9
U-15	**115**	14.6 ± 0.3	167.1 ± 7.3	86.5 ± 4.8	80.5 ± 3.9	54.7 ± 8.4	19.5 ± 2.1
U-16	**112**	15.6 ± 0.3	171.8 ± 5.8	90.3 ± 3.6	81.5 ± 4.1	61.6 ± 6.7	20.9 ± 1.9
U-17	**106**	16.6 ± 0.3	173.7 ± 5.4	91.8 ± 3.1	81.9 ± 4.3	64.1 ± 6.3	21.2 ± 1.7
U-18	**108**	17.6 ± 0.3	173.5 ± 5.8	91.2 ± 3.0	82.3 ± 4.7	65.8 ± 8.0	21.8 ± 2.1
U-19	**17**	18.4 ± 0.3	170.3 ± 8.0	89.1 ± 3.0	82.1 ± 5.1	69.8 ± 7.5	20.4 ± 0.5

Table 2. All physeal pathologies presented by frequency (%), incidence per squad†/season (95%CI), severity (mean ± SD) and burden in days (95%CI). * AIIS: Anterior inferior iliac spine; **ASIS: Anterior superior iliac spine. † The rate per squad per season is established on a squad of 25 players.

Pathologies	Frequency		Incidence		Severity		Burden	
	Overall	Time-loss injuries	Overall	Time-loss injuries	Mean ± SD	Min-Max	Total	Per Squad†/season
Physis *Diagnosis* *Location*	N (%)	N (%)	Per squad†/season (95%CI)		Days	Days	Days	Days (95%CI)
Physeal injuries	**26 (8.5)**	**25 (10.2)**	**0.6 (0.4-0.9)**	**0.6 (0.4-0.8)**	**53.7 ± 71.8**	**1-352**	**1343**	**30.8 (29.2-32.5)**
Salter-Harris type I	***10 (38.5)***	***9 (36)***	0.2 (0.1-0.4)	0.2 (0.1-0.4)	***35.9 ± 18.2***	***1-58***	***323***	***7.4 (6.6-8.3)***
Distal forearm	*5 (19.2)*	*4 (44.5)*	*0.1 (0.04-0.3)*	*0.1 (0.02-0.2)*	*21.5 ± 15.9*	*1-39*	*86*	*2.0 (1.6-2.4)*
Distal femoral	*2 (7.7)*	*2 (22.2)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*48.0 ± 14.1*	*38-58*	*96*	*2.2 (1.8-2.7)*
Proximal lower leg	*1 (3.8)*	*1 (11.1)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*43*	*/*	*43*	*1.0 (0.7-1.3)*
Distal lower leg	*2 (7.7)*	*2 (22.2)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*49.0 ± 12.7*	*40-58*	*98*	*2.2 (1.8-2.7)*
Salter-Harris type II	***10 (38.5)***	***10 (40)***	0.2 (0.1-0.4)	0.2 (0.1-0.4)	***31.9 ± 27.3***	***2-86***	***319***	***7.3 (6.5-8.2)***
Distal forearm	*3 (11.5)*	*3 (30)*	*0.07 (0.01-0.2)*	*0.07 (0.01-0.2)*	*24.3 ± 5.7*	*21-31*	*73*	*1.7 (1.3-2.1)*
Hand-finger	*5 (19.2)*	*5 (50)*	*0.1 (0.04-0.3)*	*0.1 (0.04-0.3)*	*16.8 ± 10.7*	*2-26*	*84*	*1.9 (1.5-2.4)*
Distal femoral	*2 (7.7)*	*2 (20)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*81 ± 7.1*	*76-86*	*162*	*3.7 (3.2-4.3)*
Salter-Harris type III	***2 (7.7)***	***2 (8)***	0.05 (0.01-0.2)	0.05 (0.01-0.2)	***31.0 ± 7.1***	***26-36***	***62***	***1.4 (1.1-1.8)***
Distal forearm	*1 (3.8)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*26*	*/*	*26*	*0.6 (0.4-0.9)*
Proximal lower leg	*1 (3.8)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*36*	*/*	*36*	*0.8 (0.6-1.1)*
Salter-Harris type IV	***2 (7.7)***	***2 (8)***	0.05 (0.01-0.2)	0.05 (0.01-0.2)	***106.5 ± 103.9***	***33-180***	***213***	***4.9 (4.2-5.6)***
Distal forearm	*1 (3.8)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*33*	*/*	*33*	*0.8 (0.5-1.1)*
Distal femoral	*1 (3.8)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*180*	*/*	*180*	*4.1 (3.5-4.8)*
Others	***2 (7.7)***	***2 (8)***	0.05 (0.01-0.2)	0.05 (0.01-0.2)	***213 ± 196.6***	***74-352***	***426***	***9.8 (8.9-10.7)***
Proximal lower leg	*2 (7.7)*	*2 (100)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*213 ± 196.6*	*74-352*	*426*	*9.8 (8.9-10.7)*
Epiphyseal injuries	**2 (0.7)**	**2 (0.8)**	**0.05 (0.01-0.2)**	**0.05 (0.01-0.2)**	**97.5 ± 128.0**	**7-188**	**195**	***4.5 (3.9-5.1)***
Slipped Capital Femoral Epiphysis	*1 (50)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*188*	*/*	*188*	*4.3 (3.7-5.0)*
Little league shoulder	*1 (50)*	*1 (50)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*7*	*/*	*7*	*0.2 (0.1-0.3)*
Apophyseal injuries	**262 (85.3)**	**202 (82.4)**	**6.0 (5.3-6.8)**	**4.6 (4.0-5.3)**	**19.1 ± 26.3**	**1-241**	**3867**	**88.6 (85.8-91.4)**
Osteochondroses	***240 (91.6)***	***180 (89.1)***	***5.5 (4.8-6.2)***	***4.1 (3.5-4.8)***	**16.1 ± 24.4**	1-241	***2911***	***66.7 (64.3-69.2)***
Sever disease	*28 (10.6)*	*19 (10.6)*	*0.6 (0.4-0.9)*	*0.4 (0.3-0.7)*	*14.4 ± 17.2*	*1-64*	*274*	*6.3 (5.6-7.1)*
Iselin disease	*2 (0.8)*	*2 (1.1)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*12.2 ± 15.5*	*1-23*	*24*	*0.5 (0.4-0.8)*
Kholer disease	*3 (1.1)*	*2 (1.1)*	*0.1 (0.01-0.2)*	*0.05 (0.01-0.2)*	*25.0 ± 26.9*	*6-44*	*50*	*1.1 (0.9-1.5)*
Osgood-Schlatter disease	*74 (28.1)*	*50 (27.8)*	*1.7 (1.3-2.1)*	*1.1 (0.9-1.5)*	*22.1 ± 41.1*	*1-241*	*1107*	*25.4 (23.9-26.9)*
Sinding-Larson-Johansson disease	*16 (6.1)*	*13 (7.2)*	*0.4 (0.2-0.6)*	*0.3 (0.2-0.5)*	*11.4 ± 7.2*	*1-27*	*148*	*3.4 (2.9-4.0)*
Iliac crest	*5 (1.9)*	*3 (1.6)*	*0.1 (0.04-0.3)*	*0.07 (0.01-0.2)*	*16.3 ± 15.5*	*5-34*	*49*	*1.1 (0.8-1.5)*
*AIIS**	*42 (16)*	*31 (17.3)*	*1.0 (0.7-1.3)*	*0.7 (0.5-1.0)*	*11.6 ± 9.8*	*1-40*	*360*	*8.2 (7.4-9.1)*
*ASIS***	*15 (5.7)*	*12 (6.7)*	*0.3 (0.2-0.6)*	*0.3 (0.1-0.5)*	*13.8 ± 9.5*	*1-27*	*166*	*3.8 (3.2-4.4)*
Ischium	*8 (3)*	*6 (3.3)*	*0.2 (0.1-0.4)*	*0.1 (0.1-0.3)*	*13.8 ± 6.1*	*3-20*	*83*	*1.9 (1.5-2.4)*
Lesser trochanter	*17 (6.5)*	*17 (9.4)*	*0.4 (0.2-0.6)*	*0.4 (0.2-0.6)*	*13.0 ± 13.9*	*1-57*	*221*	*5.1 (4.4-5.8)*
Greater trochanter	*1 (0.4)*	*/*	*0.02 (0.0-0.1)*	*/*	*/*	*/*	*/*	*/*
Pubic	*29 (11)*	*25 (13.9)*	*0.7 (0.4-1.0)*	*0.6 (0.4-0.8)*	*17.2 ± 17.0*	*1-62*	*429*	*9.8 (8.9-10.8)*
Avulsion fracture	***22 (8.4)***	***22 (10.9)***	***0.5 (0.3-0.8)***	***0.5 (0.3-0.8)***	**43.5 ± 28.8**	**23-126**	**956**	***21.9 (20.5-23.3)***
Shoulder-elbow	*2 (0.8)*	*2 (9.1)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*41.0 ± 4.2*	*38-44*	*82*	*1.9 (1.5-2.3)*
Hand-finger	*2 (0.8)*	*2 (9.1)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*13.0 ± 9.9*	*38-44*	*26*	*0.6 (0.4-0.9)*
Iliac crest	*1 (0.4)*	*1 (4.5)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*126*	*/*	*126*	*2.9 (2.4-3.4)*
*AIIS**	*12 (4.6)*	*12 (54.7)*	*0.3 (0.1-0.5)*	*0.3 (0.1-0.5)*	*37.7 ± 10.1*	*25-55*	*452*	*10.4 (9.4-11.4)*

*ASIS***	*2 (0.8)*	*2 (9.1)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*32.0 ± 12.7*	*23-41*	*64*	*1.5 (1.1-1.9)*
Ischium	*1 (0.4)*	*1 (4.5)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*28*	*/*	*28*	*0.6 (0.4-0.9)*
Patella sleeve	*1 (0.4)*	*1 (4.5)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*55*	*/*	*55*	*1.3 (0.9-1.6)*
5th metatarsal	*1 (0.4)*	*1 (4.5)*	*0.02 (0.0-0.1)*	*0.02 (0.0-0.1)*	*123*	*/*	*123*	*2.8 (2.3-3.4)*
Others physis injuries	**17 (5.5)**	**16 (6.5)**	**0.4 (0.23-0.62)**	**0.4 (0.21-0.60)**	**91.1 ± 63.7**	**1-221**	**1457**	**33.4 (31.7-35.1)**
Bi-partita	***5 (29.4)***	***5 (31.2)***	***0.1 (0.04-0.3)***	***0.1 (0.04-0.3)***	***19.8 ± 12.5***	***1-32***	***99***	***2.3 (1.8-2.8)***
Patella	*2 (40)*	*2 (40)*	*0.05 (0.01-0.2)*	*0.05 (0.01-0.2)*	*24.0 ± 11.3*	*16-32*	*48*	*1.1 (0.8-1.5)*
Sesamoid	*3 (60)*	*3 (60)*	*0.07 (0.01-0.2)*	*0.07 (0.01-0.2)*	*17.0 ± 14.7*	*1-30*	*51*	*1.2 (0.9-1.5)*
Scheuermann's disease	***1 (5.9)***	*/*	***0.02 (0.0-0.1)***	*/*	*/*	*/*	*/*	*/*
Spondylolysis	***11 (64.7)***	***11 (68.8)***	***0.3 (0.1-0.5)***	***0.3 (0.1-0.5)***	***123.4 ± 48.2***	***61-221***	***1358***	***31.1 (29.5-32.8)***
Total	**307 (100)**	**245 (100)**	**7.0 (6.3-7.9)**	**5.6 (4.9-6.4)**	**28.0 ± 42.8**	**1-352**	**6862**	**157.2 (153.5-161.0)**

FIGURES LEGENDS

Figure 1. Summary of all physeal injuries by body-parts: Prevalence: Overall – time-loss injuries; Percentage of the total lay-off; Injury mean lay-off (Minimum-Maximum); Burden per squad-season (95%CI); Mean median age (Interquartile 25-75). *The squad-season is based on a group of 25 players.

Figure 2. Risk matrix based on the severity (duration of median time-loss) and incidence depicted by age group, illustrating the burden for all physeal injuries. Grey lines represent points with equal burden (days per squad-season). The vertical and horizontal error bars represent 95% CIs.

Figure 3. Physis injuries by chronological age: Median and interquartile range (black box); SD values (whisker). Anatomical locations affected only once are not included in the figure.

Figure 4. Risk matrix based on the severity (duration of median time-loss) and incidence depicted by the main lower limb location, illustrating the burden for all physeal injuries. Grey lines represent point with equal burden (days per squad-season). The vertical and horizontal error bars represent 95% CIs.

Figure 5. Incidence of lower limb apophyseal injuries depicted by foot-ankle, knee and hip-pelvis per squad-season for each age groups. Error bars represent 95% CI. † Substantial change ($p<0.05$) with the previous similar location.

Figure 6 Risk matrix based on the duration of time-loss injuries illustrating the burden for all lower limb apophyseal injuries depicted by osteochondrosis (○) and avulsion (▲). The severity is illustrated by the median (time-loss days) and incidence of injury/squad season (25 players). Grey lines represent point with equal burden (days per squad-season). The vertical and horizontal error bars represent 95% CIs. The square frame display only the osteochondrosis for clarity.