Injury patterns differ with age in male youth football: a four-season prospective study of 1111 time-loss injuries in an elite national academy

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ABSTRACT

Objectives To describe age group patterns for injury incidence, severity and burden in elite male youth football.

Methods Prospective cohort study capturing data on individual exposure and time-loss injuries from training and matches over four seasons (2016/2017 through 2019/2020) at a national football academy (U13–U18; age range: 11–18 years). Injury incidence was calculated as the number of injuries per 1000 hours, injury severity as the median number of days lost and injury burden as the number of days lost per 1000 hours.

Results We included 301 players (591 player-seasons) and recorded 1111 time-loss injuries. Overall incidence was 12.0 per 1000 hours (95% CI 11.3 to 12.7) and burden was 255 days lost per 1000 hours (252 to 259). The mean incidence for overall injuries was higher in the older age groups (7.8 to 18.6 injuries per 1000 hours), while the greatest burden was observed in the U16 age group (425 days; 415 to 435). In older age groups, incidence and burden were higher for muscle injuries and lower for physis injuries. Incidence of joint sprains and bone stress injuries was greatest for players in the U16, U17 and U18 age groups, with the largest burden observed for U16 players. No clear age group trend was observed for fractures.

Conclusion Injury patterns differed with age; tailoring prevention programmes may be possible.

INTRODUCTION

Reducing the impact of football injuries will improve the health status of young players and maximise opportunities for development and, ultimately, performance.[1 2] To achieve this, it is essential to first gain a thorough understanding of the problem.[3 4]

Although the overall injury patterns for elite male youth football players seem to be similar to senior players,[2] specific injury trends throughout the developmental process are not well described. The adolescent elite athlete is exposed to intense training and match programmes while transitioning from child to an adult, a process characterised by immature tissue and periods of rapid growth.[5–9] This may explain the elevated rates of growth-related injuries and greater injury burden observed around the age where height and weight typically change the most.[10–16]

Methodological variations in studies on youth football have led to wide ranges in reported injury outcomes.[2] Different injury definitions and recording methods, inconsistent injury classification, short observation periods and small samples limit the ability to compare contexts and reach meaningful conclusions. Furthermore, studies most often focus only on the rate of injuries, without considering the impact of each injury on participation. While injury incidence accounts for how often injury events occur, understanding injury burden is also important.[17–19] Specifically, taking the severity of each injury into account might enable more clinically precise comparisons of 'rare but severe injuries' (eg, ACL tears and fractures) and 'common but minor injuries' (eg, contusions and spasms).[17–19]

In professional football academies, identifying the injuries which limit participation in training and matches is fundamental to inform the implementation of prevention programmes and optimise player development. The aim of this study was therefore to describe age-related injury patterns for incidence, severity and burden in elite male youth players.

METHODS

Study population

This study used data collected prospectively over four seasons at the Aspire Academy, an elite male national football academy in Qatar. The participants were players aged 11–18 years enrolled in the football programme (U13–U18) for the 2016/2017 through the 2019/2020 seasons. Full-time players typically participated in eight morning or afternoon academy sessions during the school week, in addition to weekend games in the national youth league with their local club. Part-time players typically participated in five afternoon academy sessions in addition to weekend club games. Written informed consent to use regularly collected injury and football exposure data for research purposes was obtained from the athlete's guardians. Participants were not included in the design or interpretation of the study.

Injury surveillance

Injuries were recorded prospectively by each squad's designated sports physiotherapist to a spreadsheet database following the consensus procedures for football outlined by Fuller *et al*.[20] The physiotherapists were present during all team sessions and updated records continuously. The Aspire Academy Football Injury Surveillance Programme was supervised by a senior physiotherapist for the first two seasons and a researcher for the last two seasons, who revised the injury records each month. Only time-loss injuries were included, defined as any physical complaint leading to the medical staff partially or fully restricting participation in future team football activities.

Injuries were classified according to their diagnoses, verified by the team physiotherapist and confirmed by a medical doctor, based on the Sports Medicine Diagnostic Coding System (SMDCS).[21] For each injury, the date of injury, session type, contact type and specific mechanism were reported. A player was considered injured until the date he returned to full participation in team training and was available for match selection as determined by the medical staff.[20] Return dates were estimated by the treating clinician if a player left the academy before returning to full participation and if an injury was still ongoing at the end of the observation period.[20]

Recording of training and match exposure

Daily individual training and match exposure data were recorded in a spreadsheet database by the designated team sports scientist. Exposure was collected for individual player activities, including information about the session type and any deviations from the main team activity (eg, absence, rehabilitation session or illness) as well as the duration of the session in minutes. The duration of club activities was collected from club strength and conditioning staff and individual match duration was corrected retrospectively against official federation match reports.

Data handling and statistical analyses

Following the completion of the data collection, injuries were reclassified by a researcher to match the updated 2020 SMDCS[22] and IOC consensus statement[18] categories for diagnosis, region, body part, tissue type and pathology type. Proximal adductor injuries could not be accurately differentiated from mid/distal injuries and therefore all adductor injuries were considered as thigh injuries as per the original SMDCS code. Onset was classified retrospectively based on the reported mechanism and diagnosis. Mechanisms indicating identifiable events (eg, 'sprinting' or 'change of direction') were considered as sudden onset, while 'gradual onset/overuse' indicated a gradual onset injury. When the specific mechanism was not available, the diagnosis was used to determine the most appropriate category (eg, strains as sudden onset and apophysitis as gradual onset).

Two separate definitions were used to describe the extent of recurrent injuries: the first using the whole observation period for the player as a reference ('overall recurrent injury') and the second using injuries during the same season only ('same-season recurrent injury'). Where the same-season definition likely underestimates the proportion of recurrent injuries, especially for severe pathologies,[23] it is less affected by differences in duration of follow-up between players (multiple injuries are more likely in players with longer observation time).[24] Complete operational definitions used in the study are provided in table 1.

The injury database was controlled against the exposure database to identify missing injuries and to verify the start and return dates for each injury. If a potential injury was identified, the player's electronic medical record (Millennium Power Chart, Cerner, North Kansas City, Missouri, USA) was audited for additional injury entries and missing details. Injuries occurring outside football activities were discarded. Exposure accumulated during periods where a player was not considered fully available due to an injury (eg, for rehabilitation sessions or partial participation in team activities) was excluded and players joining or leaving the academy during a season were censored for the period they were not regularly monitored by academy staff.

Descriptive statistics, season incidence proportion and average player availability are reported as percentages and means with SD.[18] Injury severity is presented as the median number of days lost (duration of restricted participation) with 25th and 75th percentiles.[18] Incidence was calculated as the number of time-loss injuries per 1000 player hours, including recurrent injuries, and burden as the number of time-loss days per 1000 player hours.[18,20,25] Uncertainty for the point incidence and burden is presented as 95% CI assuming a Poisson distribution.[26]

RESULTS

Over the four-season observation period, 724 player-seasons with recorded training or match exposure were screened for eligibility. Of these, 133 were excluded from the analyses as they were not registered full-time or part-time players (n=58), did not regularly attend academy sessions (n=53), joined after the observation period ended (n=17) or did not participate at all during the entire season due to an injury sustained in the previous season (n=5; four ACL tears and one osteochondral lesion). The final sample included 301 unique players (133 players followed for one season, 83 for two seasons, 48 for three seasons and 37 for four seasons) contributing to 591 player-seasons (mean age at the start of the season: 14.6, SD 1.6 years). The flow of players joining and leaving the academy throughout the study is shown in figure 1. The total accumulated exposure was 78 069 training

Table 1 Operational definitions used in the study

Measure	Definition
Player-season	One player participating in one given season.
Training exposure	Team-based and individual physical activities under the control or guidance of the team's coaching or fitness staff that are aimed at maintaining or improving football skills or physical condition.[20]
Match exposure	Play between teams from different clubs, academies or federations.[20]
Time-loss injury	Any physical complaint or manifestation experienced by a player that requires the medical staff to fully or partially restrict participation in a future football team training session or match.[20]
Injury incidence	The number of time-loss injuries per 1000 player hours.[20,25]
Season incidence proportion	The proportion of players with at least one recorded time-loss injury for a given season.[25]
Overall recurrent injury	A time-loss injury to the same location with the same pathology type as a previously recorded injury during the observation period, following return to full participation from the previous event.[18]
Same-season recurrent injury	A time-loss injury to the same location with the same pathology type as a previously recorded injury during the same season, following return to full participation from the previous event.[18]
Injury burden	A measure of the injury impact, taking both incidence (how often) and severity (duration) into account. Calculated as the total days lost per 1000 player hours.[17,18]
Player availability	The proportion of fully available players (not restricted by injury) for training and match entries in the exposure database.[18]

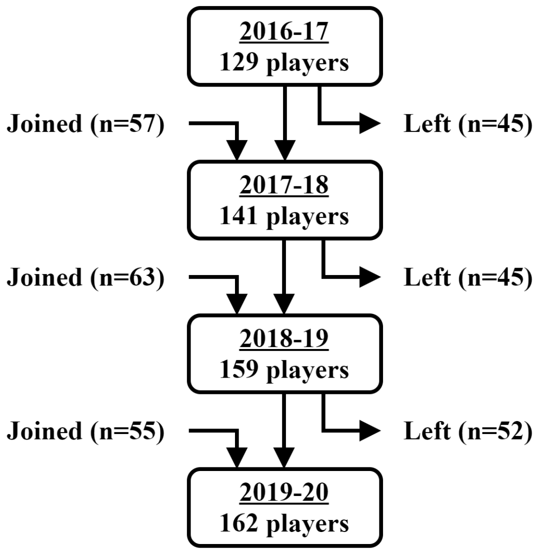

Figure 1 Player flow during the observation period.

hours and 14 758 match hours with a median season duration of 36 weeks (25–75th percentile: 29–38).

Main injury outcomes

A total of 1111 time-loss injuries were included for analysis during the observation period (1.9, SD 1.8 per player-season). A further 61 injuries sustained outside of football activities were excluded. The overall incidence was 12.0 injuries per 1000 hours (95% CI 11.3 to 12.7) and was similar in full-time (11.8, 11.0 to 12.6) and part-time (12.9, 11.1 to 14.8) players. Incidence during match play (32.0 per 1000 hours, 29.2 to 35.0) was 3.9 times greater compared with training (8.2 per 1000 hours, 7.6 to 8.8). The proportion of players sustaining at least one injury during a season (cumulative incidence proportion) was 78.5%. Overall recurrent injuries accounted for 12.0% of the time-loss episodes with same-season recurrent injuries accounting for 7.5%. Overall player availability was 85.8% (85.1% and 89.6% for training sessions and matches, respectively). Injury outcomes by age group are presented in table 2 and seasonal data are available in online supplemental table 1.

The total number of days lost was 23 713, resulting in an overall burden of 255 days lost per 1000 hours (252 to 259). The burden was lower in full-time players (233 days, 229 to 236) compared with part-time (375 days, 365 to 384) players. Return dates were estimated in 30 cases (2.7%). Median severity was 8 days per injury (2 to 21), with similar severity for training injuries (8 days, 2 to 20) and match injuries (9 days, 3 to 22). The burden of match injuries (717 days per 1000 hours, 704 to 731) was 4.3 times greater than for training injuries (168 days per 1000 hours, 165 to 171). A risk matrix displaying the overall incidence and severity for each age group is presented in figure 2.

Onset and mechanism

The majority of injuries were retrospectively classified as sudden onset (75%) with the remaining 25% as gradual onset. The incidence of gradual onset injuries was similar in full-time (3.1, 2.7 to 3.5) and part-time (2.6, 1.8 to 3.6) players. Non-contact injuries represented 60% of the total, with contact mechanisms accounting for 38% (24% direct contact by player, 11% direct contact by ball/object and 4% indirect contact by player; 2% missing). The specific mechanism was missing or reported as 'other/unknown' for 31% of the injuries, while 23% were the result of duels (tackled, tackling or kicked), 18% from gradual onset/overuse, 10% from sprinting and 5% from shooting or passing.

Diagnosis, tissue and pathology type

The lower limbs were most commonly injured (83%), followed by the upper limbs (9%), trunk (6%) and head/neck (2%). The incidence, severity and burden for the most relevant pathology types and diagnoses are presented in table 3.

The tissue types with the greatest incidence were muscle/tendon (3.2 injuries per 1000 hours, 2.9 to 3.6; 27% of all injuries), bone (2.8, 2.4 to 3.1; 23%), superficial tissues/skin (2.2, 1.9 to 2.5; 18%), ligament/joint capsule (1.5, 1.3 to 1.8; 13%) and non-specific (1.4, 1.2 to 1.7; 12%). Bone injuries were the most burdensome (87 days per 1000 hours, 85 to 89; 34% of all days lost), followed by ligament/joint capsule (78, 77 to 80;

Table 2 Demographic, exposure and injury data per age group for the combined four-season observation period

	U13	U14	U15	U16	U17	U18
Player-seasons	102	106	117	102	92	72
Age (years, SD)	12.3 (0.3)	13.3 (0.3)	14.3 (0.3)	15.3 (0.3)	16.3 (0.3)	17.3 (0.3)
Stature (cm, SD)	153.6 (7.5)	160.4 (7.9)	168.6 (6.6)	172.0 (6.4)	174.9 (7.0)	176.2 (7.4)
Body mass (kg, SD)	41.7 (6.4)	48.0 (8.3)	55.7 (7.6)	60.3 (6.8)	65.0 (7.8)	66.8 (8.7)
Total accumulated training exposure (hours)	15 094	16 726	14 803	12 903	11 203	7340
Total accumulated match exposure (hours)	1978	2519	3062	2816	2535	1848
Time-loss injuries (n)	133	164	194	215	234	171
Overall injury incidence (95% CI)	7.8 (6.5 to 9.2)	8.5 (7.3 to 9.9)	10.9 (9.4 to 12.5)	13.7 (11.9 to 15.6)	17.0 (14.9 to 19.4)	18.6 (15.9 to 21.6)
Training injury incidence (95% CI)	6.0 (4.9 to 7.4)	6.3 (5.1 to 7.6)	7.4 (6.0 to 8.9)	8.8 (7.3 to 10.6)	11.0 (9.1 to 13.1)	13.2 (10.7 to 16.1)
Match injury incidence (95% CI)	21.2 (15.3 to 28.7)	23.4 (17.8 to 30.2)	27.8 (22.2 to 34.3)	35.9 (29.2 to 43.6)	43.8 (36.0 to 52.7)	40.0 (31.4 to 50.3)
Season incidence proportion (%)	65.7	75.5	76.1	92.2	82.6	80.6
Overall recurrent injuries (%)	6.0	9.8	10.8	11.2	16.2	15.2
Same-season recurrent injuries (%)	6.0	7.3	5.7	6.5	9.0	9.9
Median days lost per injury (25–75th percentile)	10 (3 to 23)	9 (3 to 24)	8 (3 to 21)	11 (3 to 31)	7 (2 to 19)	5 (2 to 14)
Injury burden (95% CI)	129 (123 to 134)	207 (200 to 213)	207 (200 to 213)	425 (415 to 435)	316 (307 to 326)	308 (297 to 319)
Overall player availability (%)	90.6	88.6	87.9	78.3	82.7	86.1
Player training availability (%)	90.1	88.2	87.0	77.2	82.0	85.4
Player match availability (%)	94.0	90.9	92.6	84.4	86.8	89.1

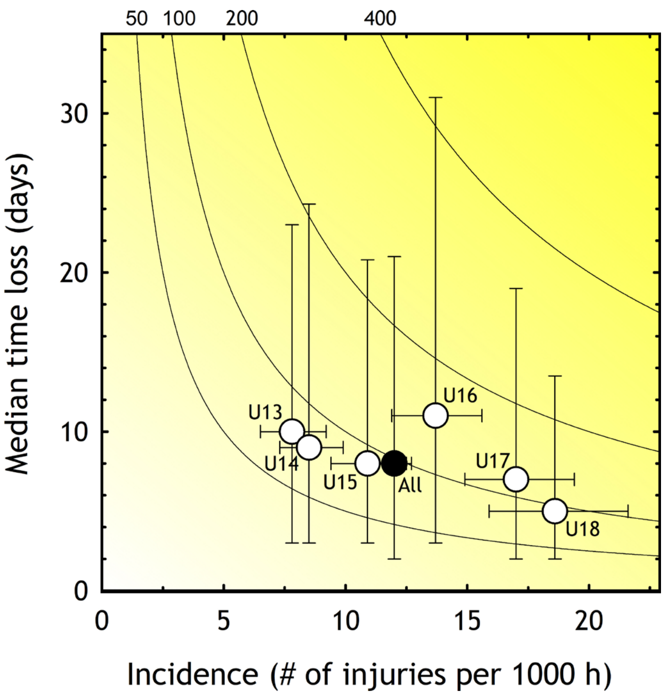

Figure 2 Risk matrix illustrating the incidence (how often) and severity (duration) of time-loss injuries per age group in a national youth football academy. A darker shade represents a greater burden and the isobars indicate equal burden lines. The horizontal error bars represent 95% CIs for incidence and vertical error bars indicate the 25th and 75th percentile for severity.

31%), muscle/tendon (42, 41 to 43; 16%), cartilage/synovium/bursa (19, 18 to 20; 8%) and superficial tissues/skin (14, 13 to 14; 5%).

For pathology types, the greatest incidence was observed for muscle injuries (2.6, 2.3 to 3.0 injuries per 1000 hours; 22% of all injuries), superficial contusions (2.1, 1.8 to 2.4; 17%), joint sprains (1.6, 1.3 to 1.8; 13%), non-specific pathologies (1.4, 1.2 to 1.7; 12%) and physis injuries (1.4, 1.1 to 1.6; 11%). The most burdensome pathology types were joint sprains (77, 75 to 79 days per 1000 hours; 30% of all days lost), followed by muscle injuries (36, 35 to 37; 14%), bone stress injuries (33, 32 to 34; 13%), fractures (33, 32 to 34, 13%) and physis injuries (19, 19 to 20; 8%).

Age group patterns

The proportion of gradual onset injuries was lower in the older age groups (U13: 33%; U14: 37%, U15: 25%, U16: 23%, U17: 21%, U18: 18%) while the proportion of injuries attributed to sprinting was greater (U13: 4%, U14: 6%, U15: 6%, U16: 9%, U17: 16%, U18: 15%). The proportion of non-contact injuries was similar between age groups (U13: 61%, U14: 68%, U15: 57%, U16: 60%, U17: 60%, U18: 56%). The incidence and severity by age group for the five most burdensome pathology types are presented as risk matrices in figure 3. The greatest incidence of joint sprains was observed for U16, U17 and U18 players, with a peak in median severity and burden in the U16 group. Muscle injury incidence and burden were the greatest in the older age groups. Bone stress injuries were more common in the U16, U17 and U18 age groups, with the greatest burden observed for U16 players. Fractures did not display any clear trend for incidence or burden, while the incidence and burden of physis injuries was the greatest in the younger age groups.

DISCUSSION

This study used observational data from four seasons in a national youth football academy (U13–U18), including 591 player-seasons and 1111 time-loss injuries. The large number of injuries and inclusion of injury burden allowed for comparisons between age groups, providing a better understanding of the impact of location-specific pathology types and diagnoses than what has previously been described. We observed age-related differences in injury pattern with higher incidence and burden of muscle injuries and lower incidence and burden of physis injuries in the older age groups. Joint sprains and bone stress injuries were reported more frequently in the three oldest age groups, with a peak burden observed for U16 players. No clear age-related trend was observed for fractures.

Injury characteristics from the same academy programme have recently been described by Materne *et al*,[16] based on data from the four seasons (2012/2013 through 2015/2016) preceding our observation period (2016/2017 through 2019/2020). We extend their work by including data on individual training and match exposure, a fundamental element to accurately describe injury incidence and burden.[18 25] Differences in exposure between age groups represent a confounder which must be taken into account when interpreting data on absolute injury rates (injuries per season/year), as injury occurrence is highly dependent on the time players spend at risk (in football activities).[23] The present data set, which includes exposure, therefore allows for direct comparisons and more nuanced interpretation, unbiased by different season durations, frequency and duration of matches and training sessions, or time lost due to injury, illness or for other reasons.

Overall injury trends

For a typical squad of 25 players, a coach in this academy could expect approximately 50 injuries and 1000 player days of restricted availability over a season, highlighting the impact injuries have on participation in young players and, consequently, on their potential for development. The overall incidence in the current study (12.0 per 1000 hours) was greater than the pooled estimates provided by Jones *et al*[2] in their systematic review of injuries in high-level youth football (5.8 for age groups U9–U21). Although similar injury rates have been reported in single studies from Germany (10.4 for U19),[27] England (12.1 for U18–U21),[28] Turkey (12.1 for U17–U19)[29] and the Netherlands (12.4 for U15 and 10.1 for U17),[14] elite players in the Middle East appear to be at the higher end of the spectrum when it comes to time-loss incidence. The underlying causes for this are not known and differences in methodology have to be taken into consideration when directly comparing results from different surveillance programmes.[18 23 30–32] The high training frequency in this academy (often two sessions per day) meant that even minor problems were likely to cause time loss,[31] and the presence of physiotherapists at every session ensured accurate recording.[31 33] While incidence was similar between full-time and part-time players, burden was lower among full-time players. This could result from closer follow-up of injured full-time players, with the opportunity for two treatment sessions per day, as opposed to one for part-time players.

Knee sprains were the primary cause of restricted participation, with 59% classified as non-contact injuries. A complete tear of the ACL was the most burdensome diagnosis and although these were not common, they led to a substantial amount of time away from football with graft ruptures or contralateral injuries occurring in all four cases prior to full recovery from

Table 3 Data on the most burdensome injuries in a national youth football academy over a four-season observation period

Body part	Injuries	Incidence rate		Median time loss		Burden	
Pathology Diagnosis	n	Injuries per 1000 hours (95% CI)		Days (25–75th percentile)		Time loss days per 1000 hours (95% CI)	
Head and neck	27	0.3	(0.2 to 0.4)	14	(7 to 18)	4	(4 to 5)
Concussion	20	0.2	(0.1 to 0.3)	16	(10 to 18)	3	(3 to 3)
Upper limb	97	1.0	(0.8 to 1.3)	16	(4 to 32)	24	(23 to 25)
Fracture	42	0.5	(0.3 to 0.6)	32	(19 to 56)	17	(17 to 18)
Forearm fracture	20	0.2	(0.1 to 0.3)	32	(22 to 55)	8	(7 to 9)
Hand/finger fracture	18	0.2	(0.1 to 0.3)	27	(17 to 43)	6	(6 to 7)
Joint sprain	20	0.2	(0.1 to 0.3)	14	(4 to 20)	3	(3 to 4)
Contusion (superficial)	33	0.4	(0.2 to 0.5)	3	(1 to 9)	3	(3 to 3)
Trunk	62	0.7	(0.5 to 0.9)	10	(2 to 43)	18	(17 to 19)
Bone stress injury	20	0.2	(0.1 to 0.3)	56	(43 to 78)	13	(13 to 14)
Spondylolysis/-listhesis	13	0.1	(0.1 to 0.2)	69	(44 to 105)	10	(9 to 11)
Pars stress reaction	6	0.1	(0.0 to 0.1)	53	(48 to 57)	3	(3 to 4)
Hip/groin	159	1.7	(1.5 to 2.0)	10	(5 to 20)	28	(27 to 29)
Physis injury	71	0.8	(0.6 to 1.0)	10	(6 to 17)	11	(10 to 11)
AIIS apophysitis	47	0.5	(0.4 to 0.7)	9	(5 to 15)	6	(5 to 6)
ASIS apophysitis	19	0.2	(0.1 to 0.3)	13	(6 to 22)	3	(3 to 4)
Bone stress injury	20	0.2	(0.1 to 0.3)	21	(11 to 37)	7	(7 to 8)
Pubic bone stress/apophysitis	19	0.2	(0.1 to 0.3)	20	(10 to 33)	5	(5 to 6)
Muscle injury	22	0.2	(0.1 to 0.4)	19	(8 to 23)	4	(4 to 5)
Iliopsoas strain/spasm	17	0.2	(0.1 to 0.3)	19	(12 to 22)	3	(3 to 4)
Non-specific pathology	23	0.2	(0.2 to 0.4)	3	(2 to 9)	2	(2 to 3)
Thigh	274	3.0	(2.6 to 3.3)	6	(2 to 16)	38	(36 to 39)
Muscle injury	179	1.9	(1.7 to 2.2)	9	(4 to 21)	29	(28 to 30)
Hamstring strain/spasm	92	1.0	(0.8 to 1.2)	9	(3 to 21)	15	(15 to 16)
Adductor strain/spasm	57	0.6	(0.5 to 0.8)	7	(3 to 15)	7	(6 to 7)
Quadriceps strain/spasm	30	0.3	(0.2 to 0.5)	16	(8 to 31)	7	(6 to 7)
Muscle contusion	40	0.4	(0.3 to 0.6)	3	(2 to 7)	4	(4 to 4)
Quadriceps contusion	37	0.4	(0.3 to 0.5)	3	(2 to 8)	4	(3 to 4)
Physis injury—*Ischial apophysitis*	6	0.1	(0.0 to 0.1)	18	(8 to 26)	1	(1 to 2)
Knee	145	1.6	(1.3 to 1.8)	8	(2 to 25)	71	(70 to 73)
Joint sprain	29	0.3	(0.2 to 0.4)	25	(17 to 167)	46	(45 to 48)
ACL complete tear	4	0.0	(0.0 to 0.1)	644	(551 to 737)	28	(27 to 29)
Patellar dislocation/subluxation	4	0.0	(0.0 to 0.1)	136	(106 to 170)	6	(6 to 7)
MCL sprain	13	0.1	(0.1 to 0.2)	17	(11 to 25)	5	(4 to 5)
Cartilage	7	0.1	(0.0 to 0.2)	47	(23 to 151)	9	(9 to 10)
Meniscal tear	6	0.1	(0.0 to 0.1)	71	(26 to 178)	9	(8 to 9)
Physis injury	34	0.4	(0.3 to 0.5)	4	(1 to 22)	6	(6 to 7)
Osgood-Schlatter's disease	33	0.4	(0.2 to 0.5)	5	(1 to 23)	6	(6 to 7)
Contusion (superficial)	35	0.4	(0.3 to 0.5)	3	(2 to 7)	2	(2 to 3)
Lower leg	100	1.1	(0.9 to 1.3)	4	(2 to 10)	14	(13 to 15)
Bone stress injury	20	0.2	(0.1 to 0.3)	21	(6 to 49)	8	(7 to 8)
Medial tibial stress syndrome	14	0.2	(0.1 to 0.3)	10	(6 to 39)	4	(4 to 5)
Lower leg stress fracture	4	0.0	(0.0 to 0.1)	54	(42 to 80)	3	(3 to 3)
Muscle injury	38	0.4	(0.3 to 0.6)	4	(1 to 9)	3	(2 to 3)
Ankle	158	1.7	(1.4 to 2.0)	11	(3 to 27)	39	(38 to 40)
Joint sprain	88	0.9	(0.8 to 1.2)	16	(5 to 36)	27	(26 to 28)
Ankle sprain (excl. syndesmosis)	78	0.8	(0.7 to 1.0)	15	(4 to 27)	18	(17 to 18)
Ankle sprain (incl. syndesmosis)	10	0.1	(0.1 to 0.2)	80	(48 to 105)	10	(9 to 10)
Synovitis/capsulitis—*Impingement*	17	0.2	(0.1 to 0.3)	21	(10 to 28)	5	(4 to 5)
Contusion (superficial)	45	0.5	(0.4 to 0.6)	3	(1 to 7)	3	(3 to 3)
Foot	89	1.0	(0.8 to 1.2)	6	(2 to 15)	19	(18 to 20)
Fracture	9	0.1	(0.0 to 0.2)	67	(43 to 96)	7	(6 to 7)
Bone stress injury	4	0.0	(0.0 to 0.1)	77	(33 to 158)	5	(4 to 5)
Non-specific pathology	11	0.1	(0.1 to 0.2)	15	(4 to 39)	3	(3 to 4)
Physis injury—*Sever's disease*	16	0.2	(0.1 to 0.3)	4	(3 to 10)	1	(1 to 1)

Injury categories were reported in the table if at least four injuries were recorded, and a total of 200 days were lost (one injury and 50 days lost per season on average). Body parts were collapsed into body regions if they did not meet the criteria, and two relevant diagnoses for youth athletes were arbitrarily included despite not meeting the required cut-off for days lost (Severs' disease and ischial apophysitis).

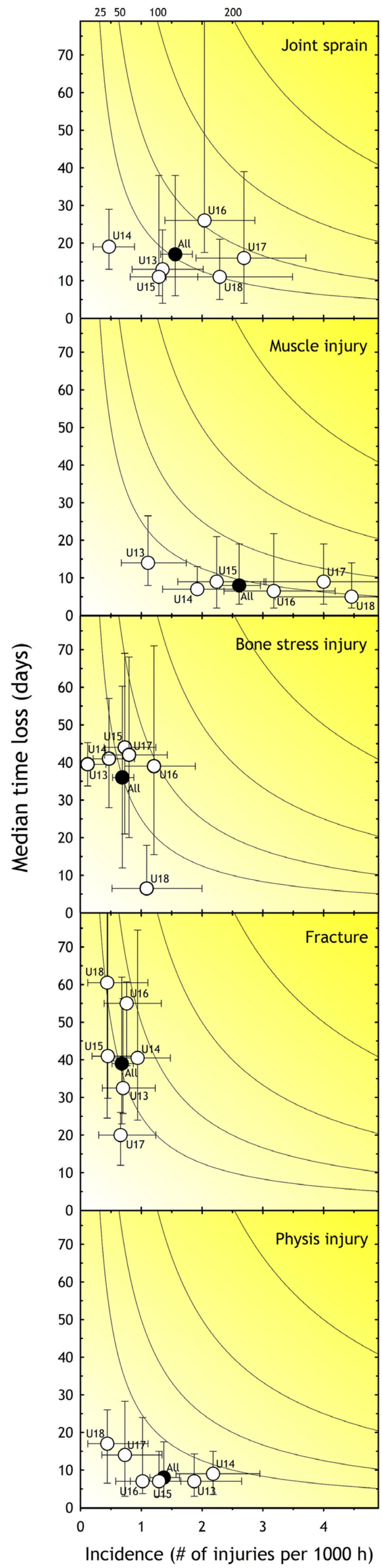

Figure 3 Risk matrices for the most burdensome pathology types in a national youth football academy. A darker shade represents a greater burden and the isobars indicate equal burden lines. The horizontal error bars represent 95% CIs for incidence and vertical error bars indicate the 25th and 75th percentile for severity.

the initial event. ACL injuries and subsequent surgical interventions are challenging in skeletally immature athletes,[34] and reinjuries and long-term health consequences are not unusual, stressing the importance of primary prevention.[35] Thigh muscle injuries and ankle sprains occurred often and were associated with moderate time loss, resulting in a high burden. In this study, 95% of thigh muscle injuries were classified as non-contact, while 58% of ankle sprains resulted from contact mechanisms. A high frequency of muscle strains and ligament sprains is in line with previous research on youth and senior football players[2 36] and reflects the nature of the game with frequent high-intensity actions and duels. Bone was the tissue type associated with the greatest burden, accounting for one third of total time loss. These injuries are especially interesting when dealing with adolescent athletes due to the immature skeletal system and growth spurt. Bone stress injuries were of particular concern in the lumbosacral area (spondylolysis-/listhesis and pars stress reactions) and should be recognised early as they are considered high-risk injuries in youth athletes.[7]

Injury patterns depend on age group

The overall injury incidence was higher in older players and more than doubled from the U13 to the U18 age group (7.8 to 18.6 per 1000 hours). A greater proportion of match versus training exposure with age should be taken into account; however, both training and match incidence were higher. Greater injury rates with age is a trend also observed in previous research, although not consistent across all studies.[2] Suggestions for underlying reasons include greater playing intensity, higher training volume, stronger players, increased competitiveness and a more aggressive playing style.[10 11 37] More advanced age, maturity and body size have indeed been associated with greater maximal aerobic and sprinting speed and match running performance in this academy.[38–40] The higher incidence could also reflect a greater likelihood of having sustained a previous injury, a commonly accepted risk factor for a new injury in youth football.[41] This is supported by a higher proportion of recurrent injuries with age in the present study.

While incidence was the greatest in the two oldest age groups, burden peaked and player availability was the lowest for U16 players. This reflects a greater severity of each injury and emphasises the importance of including burden alongside injury counts and incidence rates in epidemiological studies. Burden is not often presented for age groups, but our results match the findings from Dutch and Spanish elite youth footballers[14 15] and the observation of more severe injuries in the U14–U16 groups elsewhere.[10 13] This has mainly been attributed to players either experiencing or adjusting to rapid changes in height and weight[10 13–15] and may be compounded by the aforementioned increases in performance capacity and match demands.

Age group trends differed for specific pathology types. A higher incidence of muscle injuries in older players could again reflect greater playing demands and increased running speeds, which may also explain the greater proportion of sprint-related injuries with age. A lower incidence of physis injuries could be related to more advanced skeletal maturation status and a greater proportion of players having gone through their growth spurt, which would be expected in the older age groups.[42 43] Apophyses are considered especially sensitive to excessive and repetitive forces, which may increase following periods of rapid skeletal lengthening and muscular strength gains.[44] The observed concomitant lower incidence of physis injuries and greater incidence of muscle injuries also supports the idea that different structures represent the point of failure throughout growth and maturation, and similar mechanisms may manifest as different pathologies depending on a player's maturity status.[8] This is supported by reports of fewer osteochondral injuries and more groin strains in early maturing players and fewer tendinopathies in late maturing players of the same age.[45] Muscle injuries also appear to occur at a greater percentage of adult height compared with growth-related injuries,[46] although the degree of somatic development may not always align with skeletal maturation and the ossification of specific bones.[47 48]

Methodological considerations

A time-loss definition was applied in this study to reduce the potential bias associated with combining injury data collected by multiple physiotherapists under the supervision of different staff members[49] and allow for direct comparison with studies from other settings. Although this definition is considered reliable and captures injuries affecting participation, it likely underestimates the incidence of gradual onset injuries and complaints that only require medical attention.[50] The impact of injuries on performance, considered an important aspect by athletes, coaches and practitioners,[51] is also not well described.[52] Basing severity on participation and availability as opposed to tissue healing may have led to different injury duration and burden for two similar injuries.[53]

Diagnoses were provided by medical staff; yet, some variation should be assumed in terms of the recorded diagnoses and pathology types. Inconsistencies have been demonstrated among sports medical staff presented with similar case descriptions,[54 55] and we therefore grouped diagnoses into larger clusters, such as 'strain/spasm' and 'ankle sprain (excluding syndesmosis)', rather than reporting the specific SMDCS diagnosis. The low number of injuries within each pathology type for some age groups led to uncertain estimates and broad CIs, which should be recognised as a limitation for these comparisons. Furthermore, age groups were not unpaired and some players are represented in multiple age groups. The injury pattern of the 37 players monitored for four full seasons did, however, reflect the overall trends with seasonal variation and greater incidence with age.

The conversion from old to new SMDCS codes impaired accuracy, as some categories were more granular in the updated codes. The onset of injuries was assigned retrospectively and should therefore be interpreted with care. The SMDCS classification was not applied, as this considers physis injuries 'acute—sudden onset', which is not consistent with the mainly gradual onset clinical presentation of the apophyseal injuries recorded in this study. The 'repetitive—sudden onset' classification could also not be used with the information available. The proportion of recurrences may be underestimated, as a complete injury history was not available for all participants; the first recorded injury during the observation period for each player was therefore considered an index injury. The specific mechanism could not be cross-checked using additional data sources. This introduces uncertainty, solely reliant on the judgement of the medical staff either through direct observation on the pitch or the description by the player or coach.

While all academy, club and national team activities were recorded during the season, physical activity outside the organised sessions (eg, leisure time and school activity for part-time players) and training during the summer break were not monitored. This may have an impact on especially the gradual onset type injuries. Finally, we highlight that contextual factors inherent to training philosophies, lifestyle habits and environmental conditions require consideration when generalising the findings of this study.

What are the findings?

- ► Overall injury incidence was higher in older age groups and the greatest burden and lowest player availability was observed in the U16 age group.
- ► Injury incidence and burden was higher in older age groups for muscle injuries and in younger age groups for physis injuries. Joint sprains and bone stress injuries were more common in the U16, U17 and U18 age groups, with the greatest burden observed for U16 players. No clear trend was observed for fractures.

How might it impact on clinical practice in the future?

- ► Identifying the most common and the most burdensome injuries allows practitioners to target the injuries with the greatest impact on player participation. While evidence-based multicomponent programmes aimed at a broad range of injuries (eg, the 11+) are still regarded as best practice, practitioners may consider adapting interventions according to the age-related patterns described in this study.
- ► Generic and specific injury-type audits are valuable to inform decisions relating to the optimal youth player management in professional academies.

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