Received: 26 August 2020 | Revised: 15 January 2021 | Accepted: 22 January 2021

DOI: 10.1111/sms.13933

ORIGINAL ARTICLE

WILEY

Injuries in youth football and the relationship to player maturation: An analysis of time-loss injuries during four seasons in an English elite male football academy

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A better insight into injuries in elite-youth football may inform prevention strategies. The purpose of this prospective cohort study was to investigate the frequency, incidence, and pattern of time-loss injuries in an elite male football academy, exploring injuries in relation to age and maturation status. Across four consecutive playing seasons, playing exposure and injuries to all academy players (U'9 to U'21) were recorded by club medical staff. Maturation status at the time of injury was also calculated for players competing in U'13 to U'16 aged squads. Time-loss injury occurrence and maturation status at time of injury were the main outcome measures. A total of 603 time-loss injuries were recorded, from 190 different players. Playing exposure was 229 317 hours resulting in an overall injury rate of 2.4 p/1000 h, ranging from 0.7 p/1000 h (U'11) to 4.8 p/1000 h (U'21). Most injuries were traumatic in mechanism (73%). The most common injury location was the thigh (23%), and the most common injury type was muscle injury (29%) combining to provide the most common injury diagnosis; thigh muscle injury (17%). In U'13-U'16 players, a higher number of injuries to early-maturing players were observed in U'13-U'14 players, while more injuries to U'15-U'16 players occurred when classed as "on-time" in maturity status. Maturation status did not statistically relate to injury pattern; however, knee bone (not-fracture) injuries peaked in U'13 players while hip/groin muscle injuries peaked in U'15 players.

KEYWORDS

academy, epidemiology, football, incidence, injury, maturation, youth

1 | INTRODUCTION

Injury patterns in elite senior football have been well explored, yet for their youth counterparts there is a lack of scientific injury surveillance.[1] Further research into youth footballer injury is warranted in order to understand existing problems,[2] which may facilitate evidence-informed solutions[3] and thus help injury prevention.

In particular, the age and growth status of youth players may hold useful information in the quest to optimize player care and development. Previous research has highlighted that time-loss injuries peak in youth players between the ages of 13-16,[1,2,4], corresponding with periods of rapid physical growth.[5] There is, however, an evident lack of literature across the complete age range of academy age players (U'9-U'21), while interactions between injury occurrence and growth / maturation timing remain largely unexplored. Differences in maturation status have been shown to relate to different types, locations, and severity of injury in youth footballers,[6,7] while morphological changes[8] and performance factors[5] seem to be affected by periods of significant physical development. Comparisons between previous literature remain difficult due to methodological differences,[1] in particular the use of non-standardized injury classification, maturity measures, and under-reporting of exposure.

More longitudinal injury data from youth academies are warranted,[9] as is a clearer insight into maturation/growth to injury.[10] Overall, the lack of research attention in those considered the "future" of our professional game is somewhat surprising. The primary aim of the present study therefore was to investigate frequency, incidence, and pattern of time-loss injuries in elite-level youth male footballers across a number of consecutive playing seasons. A secondary aim was to explore these findings in relation to chronological age and status of maturation.

2 | MATERIALS AND METHODS

2.1 | Study design

A prospective cohort study of an English professional football academy was carried out over four consecutive playing seasons. The participating academy was classified as "category one," a status considered "elite" after a robust process of independent audit.[11]

2.2 | Study period and study population

Injuries and illnesses occurring between (and inclusive of) the 2015-16 and 2018-19 playing seasons were recorded and analyzed from all 10 academy squads (Under' 9,10,11,12,13,14,15,16,18,21). All recorded injuries were incurred by players registered with the club at the time of data entry. Players injured at the start of their first season were included, but their injuries at the time of enrollment were not recorded. Any players who left the club before the end of a playing season were included, but only while participating. Ethical approval was granted by the University of Chichester ethics committee in collaboration with the participating football club.

2.3 | Data collection

Player training/match exposure in minutes (daily) and anthropometric data (monthly) were recorded by employed club sport science and medicine staff. All injuries/illnesses resulting in a player being unable to fully participate in subsequent training or match were diagnosed and documented by qualified club medical staff on the day of the incident/presentation. All data were collected in-line with standard club monitoring procedures, coded according to the Orchard Sports Injury and Illness Classification System and recorded using the Performance Management Application (PMA) system. Injury definitions (Box 1) adopted from previous literature,[12,13] were then applied to the data, removing entries classed as "medical illness" or those that did not result in time loss from football activity.

2.4 | Maturation status at time of injury

For each injury that occurred while competing in the U'13, U'14, U'15, and U'16 squads, a status of maturation (classified as early, on-time or late) was calculated using the Khamis-Roche Equation.[14] This non-invasive measuring method is often used in academy football to make a prediction of adult height and identify players' peak height velocity, a period of rapid physical growth considered to increase injury susceptibility in youth players.[7] The method utilizes a combination of chronological age, standing height, body mass, and mid-parental height of biological parent(s).[15] Z-scores were subsequently calculated to estimate maturity status at the time of injury, with a player regarded as normal (z-score between –1.0 and + 1.0), early (z-score > +1.0) and late (z-score < –1.0). Academy staff recording these measures were International Society for the Advancement of Kinanthropometry (ISAK) Level 1 accredited and used standardized ISAK measurement techniques. Standing height was measured using a stadiometer (217 Stable Stadiometer; Seca) and body mass using scales (875 Flat Scales; Seca). Parental heights were either self-reported via survey or measured by academy staff. Self-reported parental heights were adjusted for overestimation.[16]

2.5 | Data analysis

Microsoft Excel (2013) was used to code player injuries/illnesses with further statistical analysis carried out using IBM SPSS Statistics version 23. Descriptive statistics are presented using frequencies and percentages, with incidence expressed as the number of injuries per-1000 h of exposure.[17]

Kruskal-Wallis tests were used to observe any differences in football exposure or injury frequency between age-groups. Planned comparisons were then conducted between consecutive age-groups (eg, U9-U10, U10-U11, etc) using Mann-Whitney tests. *P*-values were considered statistically significant at an alpha level of 0.05 and were adjusted for comparisons, using the Bonferroni correction providing a significance level for each test of $P = .0056$.

Friedman tests were used to observe any differences between age-groups for injury pattern (location, type, diagnosis) or status of maturation (at the time of injury). Planned comparisons

BOX 1 Operational definitions

	Operational definitions
Training session	Team training that involved physical activity under the supervision of the coaching staff.
Match	Competitive or friendly match against another team
Injury	Injury resulting from playing football and leading to a player being unable to fully participate in future training or match play (ie, time-loss injury).
Re-injury	Injury of the same type and at the same site as an index injury occurring no more than 2 months after a player's return to full participation from the initial injury.
Minimal Injury	Injury causing absence of 1-3 days from training and match play
Mild Injury	Injury causing absence of 4-7 days from training and match play
Moderate Injury	Injury causing absence of 8-28 days from training and match play.
Severe Injury	Injury causing absence of over 28 days from training and match play
Traumatic Injury	Injury with sudden onset and known cause.
Overuse Injury	Injury with insidious onset and no known trauma.
Injury Incidence	Number of injuries per 1000 player hours ((Σ injuries/Σ exposure hours) ×1000).

were then conducted between consecutive age-groups to examine where differences existed using Wilcoxon signed-rank tests. Chi-squared goodness-of-fit tests were used to explore associations of injury type, locations, and maturation status (U13-U16 squads). Standardized residuals (StR) > 1.96 were used to determine where the largest associations occurred.[18]

3 | RESULTS

3.1 | Injury count

A total of 701 recorded medical issues resulted in absence from training or match play during the analyzed seasons (2015-2019). Ninety-eight data entries were classed as medical illness and were removed from further analysis resulting in 603 recorded time-loss injuries, of which only 14 (2%) were classed as re-injuries. A total of 190 individual players suffered injuries. Contributions per age-group to this total figure and the number of players recording injuries across different multiple seasons are shown in Figure 1. The highest contribution came from the U'21 group = 165 (27.4%) injuries and the lowest from the U'11 group = 14 (2.3%) injuries.

3.2 | Football exposure

Detailed exposure data for each age-group, including means per-season can be found in Figure 2 and Table A1 (appendices). Match exposure (hours) for all groups between the analyzed seasons (2015-2019) was 20 357. Training exposure (hours) was 208,960 resulting in a total exposure of 229 317 hours, ranging from 8949 (U'9 group) to 34 822 (U'18 group). Between age-groups, a statistically significant difference in total exposure was found between the U'11-U'10, U'15-U'14 and U'18-U'16 age-groups, ($H(9) = 36.515$, $P < .001$).

3.3 | Injury frequency and incidence

Injury frequency, means, and incidence rates per-1000 playing hours (p/1000 h) per age-group are presented in Figure 3. Overall injury incidence was 2.4, ranging from 0.7 (U'11) to 4.8 (U'21) injuries p/1000 h.

3.4 | Nature of injuries

Most injuries occurred in the lower extremity (n = 510, 85%). Traumatic injuries were more common than overuse injuries (n = 439, 73% vs n = 164, 27%), with muscle tears/strains/cramps (n = 146, 36%), sprains (n = 114, 26%), and hematoma/contusions (n = 81, 18%) the most common traumatic injury types. Bone injury (not-fracture) (n = 77, 47%), muscle tear/strain/cramps (n = 27, 16%), and tendon tear/tendinopathy (n = 22, 13%) were the most common overuse injury types. The location and types of injury suffered according to their mechanism (traumatic or overuse) are shown in Table A2 (appendices).

The locations of injury according to squad age-groups are shown in Table 1. Overall, the four most common injury locations were the thigh (n = 137, 23%), knee (n = 104, 17%), ankle (n = 100, 17%), and hip/groin (n = 53, 9%). Between age-groups, statistically significant ($\chi 2\ (9) = 61.65$, $P < .001$) differences in injury location were observed between U'13-U'12 ($P<.001$), U'18-U'16 ($P = .004$), and U'21-U'18 ($P < .001$).

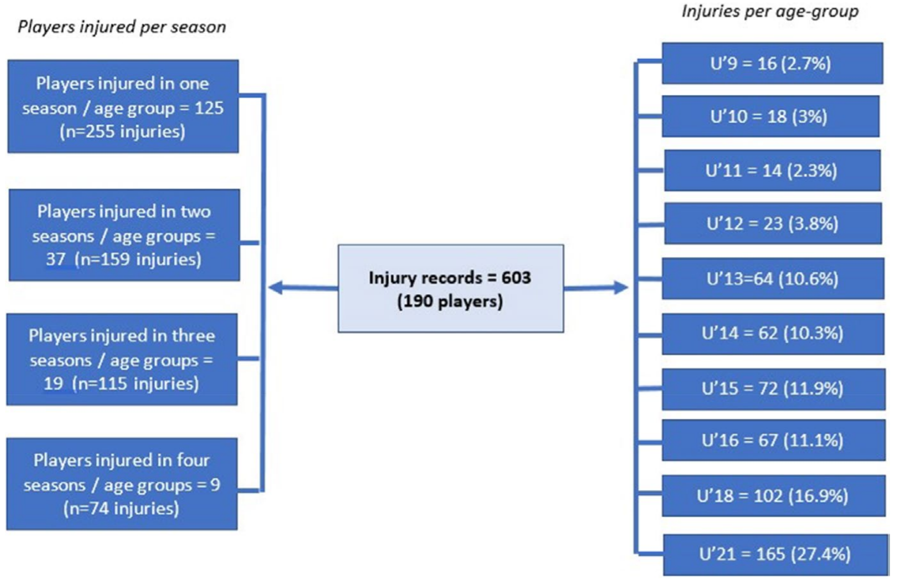

FIGURE 1 Breakdown of injury records analyzed, including age-group and player contributions

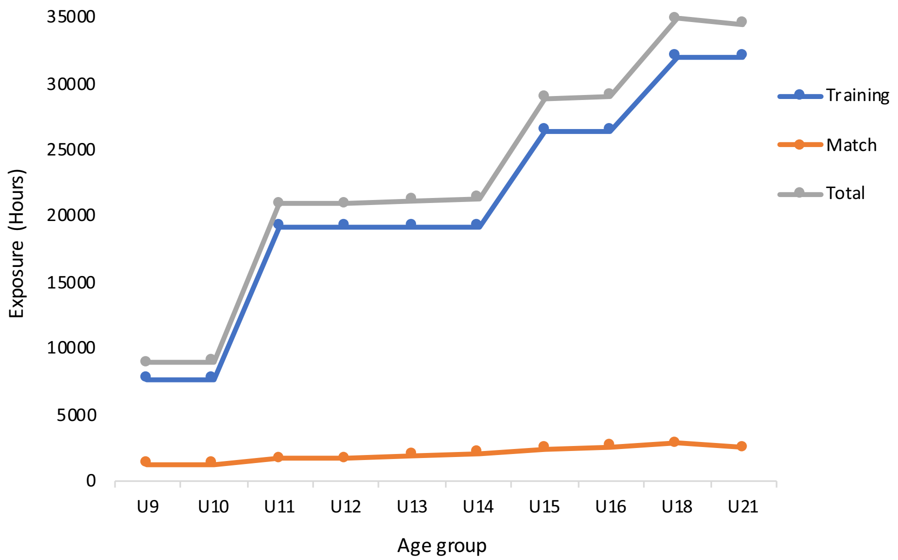

FIGURE 2 Training, match and total exposure (hours) across all seasons per age-group

Subsequently, injury location was found to have a statistically significant ($P < .001$) association with the U'13 (χ^2 (9, N = 64) = 50.0), U'18 (χ^2 (11, N = 102) = 103.0) and U'21 (χ^2 (12, N = 165) = 170.4) age-groups. The injury locations contributing most to these associations were the knee (N = 21, StR = +5.77) in the U'13 age-group and the thigh in the U'18 (N = 31, StR + 7.72) and U'21 (N = 42, StR + 8.22) age-groups.

3.5 | Injury type

The types of injury according to squad age-groups are shown in Table 1. Overall, the four most common injury types (both traumatic and overuse) recorded were muscle tear/strain/cramp (n = 173, 29%), sprain/ligament (n = 121, 20%), bone (not-fracture) (n = 89, 15%), and hematoma/contusion (n = 83, 14%). Between age-groups, statistically significant ($\chi2$ (9) = 50.72, $P < .001$) differences in injury type were observed between U'13-U'12 ($P = .015$) and U'21 - U'18 ($P = .002$).

Subsequently, injury type was found to have a statistically significant ($P < .001$) association with the U'13 (χ^2 (7, N = 64) = 53.7) and U'21 (χ^2 (11, N = 165) = 177.6) age-groups. The injury types contributing most to these associations were bone (not-fracture) injuries (N = 24, StR = +5.66) in the U'13 age-group and the muscle strain/tear/cramp in the U'21 (N = 44, StR + 8.13).

3.6 | Injury diagnoses

The four most common clinical diagnoses (injury location crossed with injury type) across all ages can be seen in Table 2. Thigh muscle tear/strain/cramp was the most common (n = 102) representing 17% of all injuries (59% of all muscle injuries). This was followed by ankle ligament/

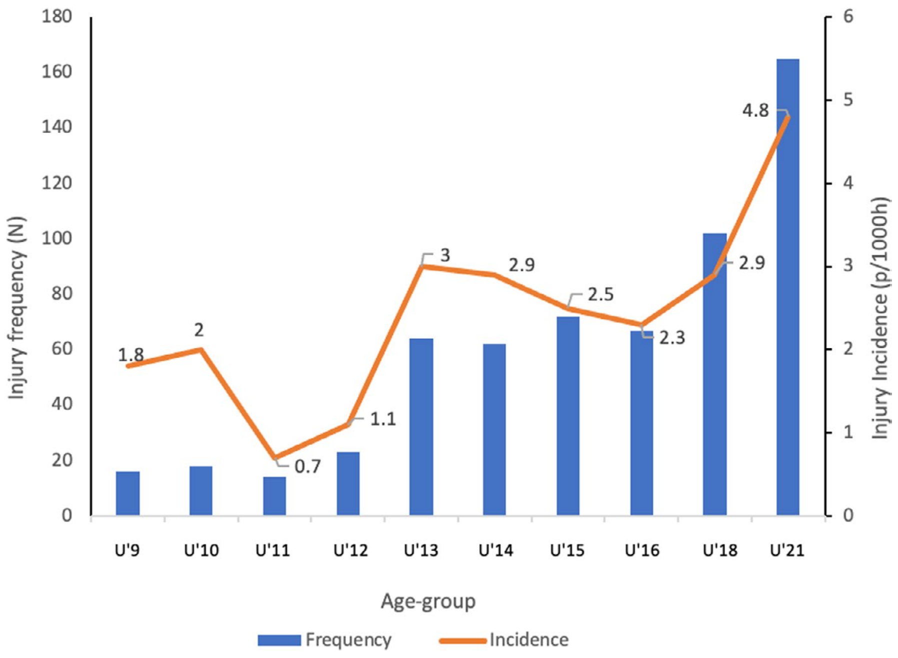

FIGURE 3 Time-loss injury frequency (N) and incidence (p/1000 h) per age-group, for all seasons analyzed

sprains (n = 72) representing 12% of all injuries (72% of all ligament /sprains), knee bone (not-fracture) injuries (n = 45) representing 7% of all injuries (51% of all bone (not-fracture) injuries), and finally hip/groin muscle tear/strain/cramp (n = 39) representing 6% of all injuries (23% of all muscle injuries). Notably, these injuries occurred most frequently in the U'21 age-group, followed by the U'18s and the U'14s. The two observed exceptions were knee bone (not-fracture) injuries peaking in U'13 (36%) players, and hip/groin muscle strains/tear/cramps peaking in U'15 (23%) players.

3.7 | Injury severity

Injury severity, according to type and location across age-groups, can also be seen in Table 2. Overall, severe injuries accounted for 37% (n = 223) of all injuries, with 35% (n = 212) regarded as moderate, 16% (n = 99) mild, and 11% (n = 69) minimal. The four most common severe diagnoses were thigh muscle strains/tear/cramp (n = 38, 17% of all severe injuries), ankle sprain/ligament (n = 37, 16%), knee bone (not-fracture) injury (n = 21, 9%), and hip/groin muscle strain/tear/cramp (n = 14, 6%). Severe injuries occurred most frequently in U'21 players (n = 67, 30%), followed by the U'18s (n = 39, 17%) and U'14s (n = 28, 13%). These observed patterns were not statistically significant between age-groups ($P > .05$).

3.8 | Maturation status and Injury pattern at time of injury (U'13-U'16 squads)

Injuries sustained by players when participating in the U'13-U'16 squads accounted for 265 (44% of total injuries). Thirty-one injury data entries did not have satisfactory measures taken required to calculate maturation status and as such were removed from further analysis. This resulted in 234 injuries (39% of total injuries) for which Z-scores were calculated. Table 3 shows the status of maturity (early, normal, or late) of the players at the time of these injuries occurring, with 71% of injuries suffered by players who were "on-time" in their maturation status. Table 3 also shows injuries proportional to the average maturation status of *all* U'13-U'16 aged players, with more injuries observed in early-maturing players in the U'13 and U'14 age-groups, while more injuries were observed in U'15-U'16 classed as maturing "on-time."

The four most common injuries suffered by players in the U'13-U'16 squads are presented in Figure 4, broken down by maturation status at the time of injury. The most common injuries across these age-groups were thigh muscle strain/tear/cramp (n = 37), peaking in the U'14 age (n = 15), knee bone (not-fracture) injuries (n = 29), peaking in the U'13 age (n = 15) and hip/groin muscle strain/tear/cramp (n = 20) peaking in the U'15 age (n = 9). There were no statistically significant differences in injury occurrence, type, or location between the different levels of maturity status ($P > .05$).

4 | DISCUSSION

A total rate of time-loss injuries for all players (U'9-U'21) of 2.4 p/1000 h exposure was recorded. This rate was previously reported in a similar elite-youth level cohort study.[19] This is despite not including the youngest age-groups (U'9-U'11) where we observed a low summative rate (1.0 p/1000 h), nor the eldest (U'21) which showed our highest rate (4.8 p/1000 h).

TABLE 1 Location and type of all injuries (4-seasons) according to squad age-groups

	U'9	U'10	U'11	U'12	U'13*	U'14	U'15	U'16	U'18*	U'21*	All (603)
Injury location											
Thigh		1 (5)	3 (21)	2 (9)	7 (11)	21 (34)	15 (21)	15 (22)	31 (30)	42 (25)	137 (23)
Knee	3 (19)	7 (39)	3 (21)	7 (30)	21 (33)	10 (17)	13 (18)	6 (9)	10 (10)	24 (15)	104 (17)
Ankle	3 (19)	4 (22)	3 (21)	5 (22)	8 (13)	4 (6)	7 (10)	14 (21)	18 (18)	34 (21)	100 (17)
Foot/Toe	4 (25)	1 (5)	3 (21)	4 (17)	10 (16)		7 (10	7 (10)	14 (14)	16 (10)	66 (11)
Hip/Groin	1 (6)	1 (5)	1 (7)	3 (13)	6 (9)	8 (13)	10 (14)	7 (10)	6 (6)	10 (6)	53 (9)
Lower leg/ Achilles		1 (5)			5 (8)	6 (10)	4 (6)	6 (9)	9 (9)	17 (10)	48 (8)
Low back/Pelvis/ Sacrum				2 (9)	1 (1)	4 (6)	10 (14)	8 (12)	2 (2)	8 (5)	35 (6)
Head/Face	3 (19)	1 (5)			1 (1)	2 (3)	3 (4)	3 (5)	4 (4)	6 (4)	23 (4)
Hand/Fingers	2 (13)		1 (7)		3 (5)	3 (5)		1 (2)	5 (5)	2 (1)	17 (3)
Wrist		1 (5)			2 (3)	2 (3)	2 (3)		1	1	9 (1)
Shoulder/ Clavicle		1 (5)				2 (3)			1	1	5
Abdomen										3 (2)	3
Elbow									1		1
Sternum/Ribs/ Thoracic										1	1
Neck/Cervical							1 (1)				1
Upper arm											
Injury type											
Muscle Tear/ Strain/Cramp	1 (6)	3 (17)	3 (21)	6 (26)	11 (17)	24 (39)	32 (44)	19 (28)	30 (29)	44 (27)	173 (29)
Sprain/Ligament	1 (6)	5 (28)	3 (21)	3 (13)	13 (20)	5 (8)	7 (10)	14 (21)	30 (29)	41 (25)	122 (20)
Bone (Not-fracture)	6 (37)	2 (11)	5 (36)	12 (52)	24 (38)	8 (13)	11 (15)	13 (19)	3 (3)	5 (3)	89 (15)
Hematoma/ Contusion	3 (19)	4 (22)	2 (14)	1 (4)	7 (11)	8 (13)	3 (4)	11 (16)	17 (17)	27 (16)	83 (14)
Fracture	2 (13)	3 (17)	1 (7)		4 (6)	4 (6)	7 (10)	5 (7)	7 (7)	8 (5)	41 (7)
Tendon Tear/ Tendinopathy					3 (5)	8 (13)	8 (11)	2 (3)	6 (6)	8 (5)	35 (6)
Concussion	1 (6)				1 (1)	2 (3)	3 (4)	1 (2)	4 (4)	6 (4)	18 (3)
Meniscus/ Cartilage						1 (2)	1 (1)	1 (2)		10 (6)	13 (2)
Other (eg, dental)		1 (5)		1 (4)					4 (4)	5 (3)	11 (2)
Dislocation/ Subluxation						1 (2)			1 (1)	5 (3)	7 (1)
Nerve Injury					1 (1)					5 (3)	6
Abrasion/ Laceration	2 (13)					1 (2)		1 (2)		1	5

*Significant difference versus preceding age-group (*P* <.05).

†Values in brackets are % of total per age-group.

‡Values < 1% not shown.

TABLE 2 The four most common injury diagnoses with levels of severity, per age-group

Injury diagnosis	U'9	U'10	U'11	U'12	U'13	U'14	U'15	U'16	U'18	U'21	All
Thigh Tear/Strain/Cramp		1	2	2	6	15	14	10	25	27	102
Minimal				1				2 (2)	1		4
Mild					1	3 (3)	3 (3)	1	1	3(2)	12
Moderate			2 (2)	1	2 (2)	5 (5)	8 (8)	5 (5)	11 (11)	14 (14)	48
Severe		1			3 (3)	7 (7)	3 (3)	2 (2)	12 (12)	10 (10)	38
Ankle Ligament/Sprain	1	3	1	1	5	2	4	9	17	29	72
Minimal	1 (1)				1 (1)		1 (1)			1 (1)	4
Mild							2 (3)		1 (1)	3 (4)	6
Moderate		2 (3)		1 (1)	1 (1)			4 (5)	7 (10	10 (14)	25
Severe		1 (1)	1 (1)		3 (4)	2 (3)	1 (1)	5 (7)	9 (12)	15 (21)	37
Knee Bone (not-fracture)	2	2	2	4	16	5	6	4	2	2	45
Minimal							1 (2)				1
Mild			1 (2)		2 (4)				1 (2)		4
Moderate	1 (2)	1 (2)	1 (2)	3 (7)	7 (16)	2 (4)	2 (4)	1 (2)		1 (2)	19
Severe	1 (2)	1 (2)		1 (2)	7 (16)	3 (7)	3 (7)	3 (7)	1 (2)	1 (2)	21
Hip/Groin Tear/Strain/Cramp	1		1	3	4	5	9	4	5	7	39
Minimal							1 (3)			1 (3)	2
Mild				1 (3)		2 (5)	3 (8)		1 (3)	1 (3)	8
Moderate	1 (3)			1 (3)	2 (5)	1 (3)	3 (8)	2 (5)	2 (5)	3 (8)	15
Severe			1 (3)	1 (3)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	14

†Values in brackets are % of all injuries of that diagnosis.

‡Values < 1% not shown.

TABLE 3 Frequency (N) of injuries according to maturation status, and proportional to the maturation status of all U'13-U'16 players

	U'13 (%)	U'14 (%)	U'15 (%)	U'16 (%)	Total
N of injuries according to maturation status					
All	58 (25)	55 (23)	61 (26)	60 (26)	234(100)
Early	15 (26)	15 (27)	9 (15)	6 (10)	45 (19)
On-time	37 (64)	36 (66)	44 (72)	49 (82)	166 (71)
Late	6 (10)	4 (7)	8 (13)	5 (8)	23 (10)
Average maturation status†					
Early	2	2.75	1.75	1.75	
On-time	7.5	8	7.25	7.5	
Late	1.25	1.5	2	1.5	
Proportion of injuries relative to average maturation status of all U'13-U'16 players					
Early	7.5	5.5	5.1	3.4	
On-time	4.9	4.5	6.1	6.5	
Late	4.8	2.7	4	3.3	

†Calculated for all participating U'13-U'16 players divided by four (seasons analyzed).

Our study appears to be the first to detail injury rates specifically in elite-level U'9 (1.8 p/1000 h) and U'10 (2 p/1000 h) squads, which along with previous literature shows that younger players have a lower injury incidence rate. A variety of external factors may contribute to this, such as increases in frequency, intensity and duration of football, game formats, and pitch-size. In the English academy football system, these changes are progressed gradually according to age-groups. This is guided by the Elite Player Performance Plan (EPPP) framework which classifies players into three phases: foundation (U'9-U'11), youth development (U'12-U'16), and professional development (U'17-U'21).

The purpose of gradual progression is in part, to minimize injury risk as rapid increases in exposure have been shown to exacerbate youth injury occurrence.[7] Therefore, it is reasonable to speculate that during the transitions between the EPPP phases, players may be vulnerable to injury due to experiencing increased exposure. However, according to our findings, the notable increases in injury rates we observed between age-groups (U'11-U'12 (80%), U'12-U'13 (166%), and U'18-U'21 (65%) did not occur simultaneously with significant increases in exposure. We did observe significant increases in exposure but these occurred in the years

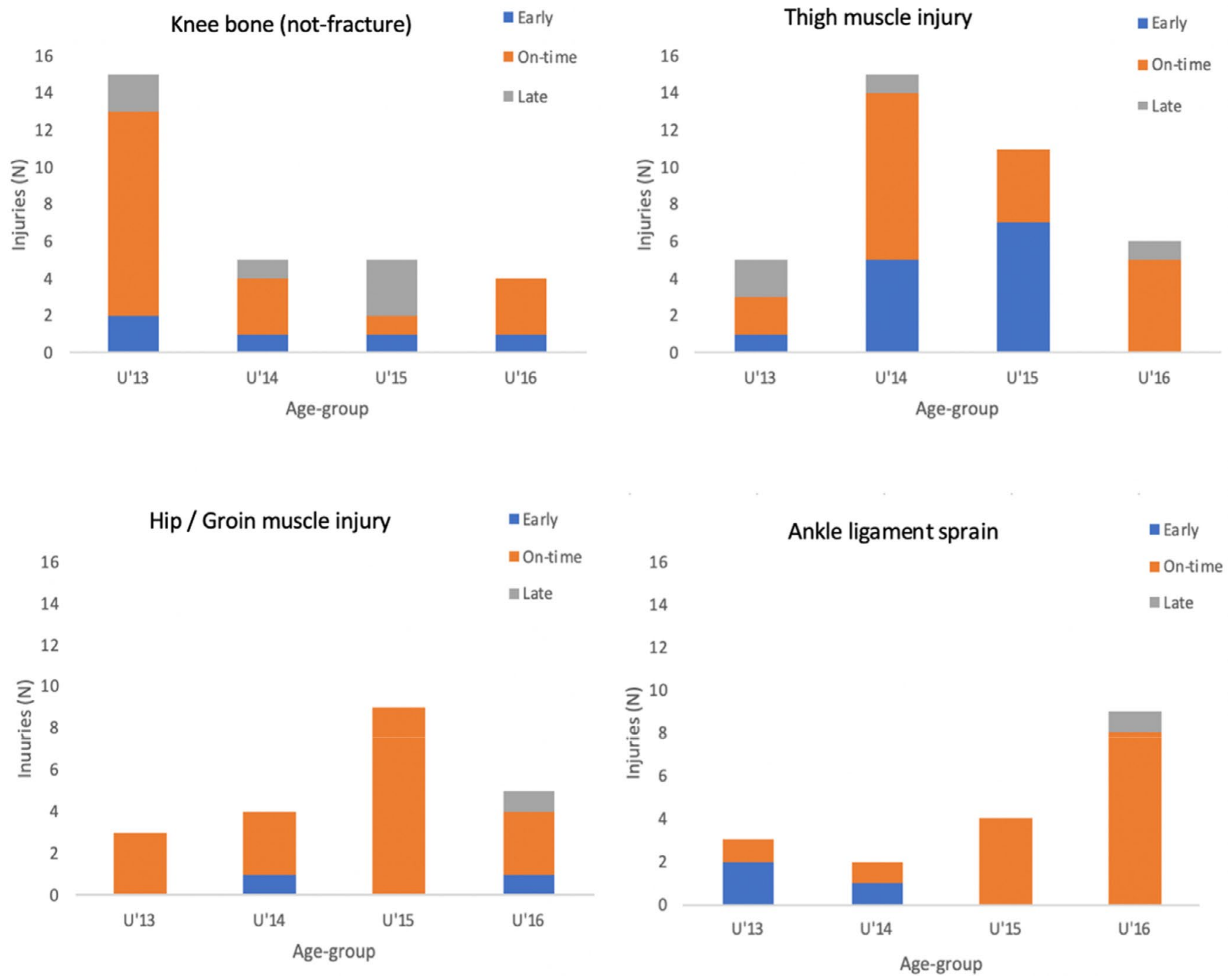

FIGURE 4 The most common injuries sustained by U'13-U'16 aged players and their maturation status at time of injury occurrence

preceding EPPP phase transition (U'10-U'11, U'14-U'15, and U'16-U'18), which may indicate how coaching staff aim to prepare players physically for the demands of the (EPPP) phase transition in the following year.

Across all players, the most common injury type we observed were muscle tears/strains/cramps, concurring with previous literature.[1,2,9,19] Similarly, our injury location findings are comparable with the thigh, knee, ankle, and hip/groin most frequently injured.[2,4,9,19] Injury location and type are of course interrelated and, when analyzing specific diagnoses, thigh muscle tear/strain/cramps were the most common and severe injury recorded. These were most notable from the age of U'15 yet particularly common in the U'18 group compared with their U'16 predecessors. This suggests that around this age, the thigh develops a significant vulnerability to injury which may be maintained into senior-level football where this injury remains common.[20] While thigh muscle injuries present a significant challenge for researchers and clinicians in adult football,[20] there may be added vulnerability in youth players due to incomplete muscle development while coping with large repetitive forces experienced with football movements.[21] These factors further coincide with less consideration for strength and conditioning regimes than their senior counterparts, which may play a protective role against injury.[22] Ultimately, further investigation into the development and management of thigh injuries in older (aged 15 +) youth players appears warranted.

Injuries to the knee showed a greater association with the U'13 age-group than any other and in particular compared to their U'12 predecessors, concurring with previous literature.[2,4] Furthermore, we observed how (not-fracture) bone injury (the third most common injury type overall) peaked in this age-group. Given that the bulk of these injuries were located at the knee (51%), it is likely due to osteochondral disorders such as Osgood-Schlatter disease, previously found to occur around the age of 13,[21] when physical adaptations increase stress on bone apophyses.[10] Comparing this finding with studies investigating similar cohorts is difficult, mainly due to a failure to report "not-fracture" bone injury as a specific entity. Therefore, the amount of bone (not-fracture) injuries we observed is much higher than previously reported, yet understandable as they would have been classified differently. Nevertheless, our findings suggest that preventative measures against knee bone (not-fracture) injury are warranted in players aged 12-13 years and appear independent of exposure levels which remained largely unchanged between the squad ages of U'11 and U'14.

A further injury *not* to linearly increase with chronological age was hip/groin muscle strain/tear/cramps which peaked in U'15 aged players. Under-15 age-group, players have previously been shown to be vulnerable to hip/groin injury,[9,19] and may be partially explained by increased changes to limb length, mass, and moments of inertia observed during periods of peak physical growth.[23,24] Such changes may impact physical characteristics such as muscle strength, where notable fluctuations may increase the risk of hip/groin injury.[25] At present, literature describing the changes in hip muscle strength across adolescent ages in elite footballers is lacking. Previous research does, however, associate youth and senior groin injury,[26] and perhaps therefore the key to reducing senior groin injury lies with increased attention and management of youth players.[27]

A secondary aim of the present study was to explore injury patterns according to maturation status in U'13-U'16 age-group players. We observed that most of these injuries occurred in players maturing "on-time" (71%) followed by early (19%) and late (10%) maturing players, yet this is arguably a typical representation of a typical breakdown of maturation status among academy players. Indeed, a previous study in elite U'14 footballers[6] reported comparable findings in classifying players (on-time = 63.5%, early = 24.5%, and late = 12%) despite adopting a more invasive measure of calculating maturation through radiographic imaging. While we observed no statistically significant differences between in injury pattern between maturation status, when injuries were considered as a proportional measure of the club's average maturation status (of all U'13-U'16 players), we found increased injuries in early-maturing players compared to those maturing "on-time" or "late." This was particularly evident in the U'13 age-group where 53% of injuries were suffered by early-maturing players compared to those classed as "on-time." Conversely, we observed how U'15 & U'16 aged players registered more injuries when classed as maturing on-time, yet this was of marginal difference. These findings are purely observational, so considering them as indicative of injury risk would be inappropriate yet may serve to direct future research exploring injury risk between maturation status groups, particularly in the notably high injury locations/types. Indeed, Le Gall et al[6] found normal and late maturing players registered more severe and osteochondral-related injuries, while early-maturing players registered more tendinopathies and groin injuries. Although our findings showed these injuries not to be statistically different between maturity status, we did observe how they peaked in distinct age-groups (U'13,bone (not-fracture) injuries, U'14,tendinopathies and U'15; hip/groin muscle injuries). These findings are somewhat comparable to a recent study observing how growth-related injuries occur more frequently in younger players.[10]

It is apparent then that specific preventative measures should be implemented in players in U'13-U'16 squads, targeting growth-related overuse injuries (both bony and tendon related) and with region-specific consideration for the knee (in U'13 players), hip/groin (in U'15 players), and thigh in players aged > 15 (in particular U'18). It is important that clinicians consider our findings alongside other epidemiological research in prioritizing medical attention to players. Indeed, survey data by Light et al[27] identified that an exponential relationship between medical management of hip/groin injuries exists with age, yet as we have highlighted, not all injuries follow this trajectory. Despite the fact that a robust injury prevention / athletic development strategy was already in place for our cohort, our findings offer coaches, conditioning, and medical staff a chance to review existing practice and consider how they may suit specific age-groups. For environments that have lesser or no strategies in place, a good starting point would be the FIFA 11 + warm-up protocol, previously shown to reduce lower-limb football injuries by 39%.[28]

4.1 | Limitations

Interpretation of our results should consider some of the inherent limitations. Firstly, within an elite academy setting there can be approximately 200 players registered. As such, a number of different medical staff are required to record injuries on the medical database. While the implicit Elite Player Performance Plan criterion for employing medical personnel with suitable qualifications was adhered to throughout the study period, possible differences in injury interpretation / diagnosis may have existed. Secondly, while we report "team-level" exposure calculations based on "normal" training and match schedules—this does not account for individual activities performed between sessions (eg, school football), nor does it accurately reflect activity intensity (high or low intensity, tactical, etc). Indeed, within the academy environment, it is typical for two age-groups to mix and train together. Therefore, age-group progression not only subjects individual players to increases in training volume but likely also intensity when training with older counterparts. Thirdly, within our age-group comparisons, there may be some interdependence in the data due to players being included in subsequent year squads; however, we believe this to be relatively low based on the numbers of injuries attributed to the same players in subsequent years Figure 1. Fourthly, the Khamis-Roche method, used in the prediction of maturation status, is based on youth of European ancestry in the Fels Longitudinal study[29]. The median error associated with this equation is 2.2 ± 0.6 cm in males between 4.0 and 17.5 years of age. Considering youth player recruitment of specific playing positions such as central defenders and goalkeepers can be based on desirable physical traits such as height, it may lead to outliers reducing the method accuracy. Finally, time-loss injury measurement underestimates the true extent of injuries,[30] well highlighted in a recent study where time-loss measurement captured just 10% of groin problems in footballers.[31] It is therefore reasonable to suggest future injury surveillance should move beyond time-loss recording as injuries may not always result in football activity absence, particularly given the gradual onset of growth-related injuries.

4.2 | Perspectives

Understanding injury pattern and associations with player age and growth should be of paramount importance to clinicians working in academy football. Common injuries we observed in this cohort showed that the hip/groin, knee, ankle, and thigh are most affected. The frequency of these injuries generally increases with age, yet there were two exceptions with knee bone (not-fracture) and hip/groin muscle injuries peaking in the U'13 and U'15 age-groups, respectively. These findings demonstrate how specific age-groups may be more likely to suffer certain injuries, which appears to occur irrespective of maturation status and/or increases in playing exposure. We hope these findings encourage further research into investigating the risk factors for such injuries and the practice of age-specific, injury prevention strategies.

CONFLICTS OF INTERESTS

None.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Light N, Johnson A, Williams S, Smith N, Hale B, Thorborg K. Injuries in youth football and the relationship to player maturation: An analysis of time-loss injuries during four seasons in an English elite male football academy. *Scand J Med Sci Sport*. 2021;31:1324–1334. https://doi.org/10.1111/sms.13933