**Title:**

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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**Source/s of financial or material support**

None

**Conflicts of Interests**

None

**Key words:**

Injury; Academy; Football; Youth; Epidemiology; Maturation; Incidence

Abstract

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/1000h, ranging from 0.7 p/1000h (U’11) to 4.8 p/1000h (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, whilst 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 whilst hip/groin muscle injuries peaked in U’15 players.

Introduction

Injury patterns in elite senior football have been well explored, yet for their youth counterparts there is a lack of scientific injury surveillance (Faude et al. 2013). Further research into youth footballer injury is warranted in order to understand existing problems (Read et al. 2018), which may facilitate evidence-informed solutions (McCunn et al. 2018) and thus help injury prevention.

In particular, the age and growth status of youth players may hold useful information in the quest to optimise player care and development. Previous research has highlighted that time-loss injuries peak in youth players between the ages of 13-16 (Faude et al. 2013; Le Gall et al. 2006; Read et al. 2018), corresponding with periods of rapid physical growth (Brownstein et al. 2018). There is however an evident lack of literature across the complete age-range of academy age players (U’9-U’21), whilst interactions between injury occurrence and growth / maturation timing remains largely unexplored. Differences in maturation status have been shown to relate to different types, locations and severity of injury in youth footballers (Le Gall et al. 2007; Van der Sluis et al. 2014), whilst morphological changes (Palmer et al. 2018) and performance factors (Brownstein et al. 2018) seem to be affected by periods of significant physical development. Comparisons between previous literature remains difficult due methodological differences (Faude et al. 2013), in particular the use of non-standardised injury classification, maturity measures and under-reporting of exposure.

More longitudinal injury data from youth academies is warranted (Renshaw and Goodwin, 2016), as is a clearer insight into maturation / growth to injury (Monasterio et al. 2020). 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.

Materials and Methods

***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 (Premier League, 2011).

***Study period and study population:*** Injuries and illnesses occurring between (and inclusive of) the 2015-16 and 2018-19 playing seasons were recorded and analysed from all ten 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 enrolment were not recorded. Any players who left the club before the end of a playing season were included, but only whilst participating. Ethical approval was granted by the University of Chichester ethics committee in collaboration with the participating football club.

***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 (Ekstrand et al. 2011; Werner et al. 2009) were then applied to the data, removing entries classed as ‘medical illness’ or those that did not result in time-loss from football activity.

***Maturation status at time of injury:*** For each injury that occurred whilst 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 (Khamis & Roche, 1995). 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 (Van der Sluis et al. 2014). The method utilises a combination of chronological age, standing height, body mass, and mid-parental height of biological parent(s) (Malina et al. 2015). 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 standardised ISAK measurement techniques. Standing height was measured using a stadiometer (217 Stable Stadiometer, Seca, Hamburg, Germany) and body mass using scales (875 Flat Scales, Seca, Hamburg, Germany). Parental heights were either self-reported via survey or measured by academy staff. Self-reported parental heights were adjusted for over estimation (Cumming et al. 2018).

***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-1000h of exposure (Philips, 2000).

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 (e.g U9-U10, U10-U11 etc) using Mann-Whitney tests. P-values were considered statistically significant at an alpha level of .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 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 (Sharp, 2015).

Results

*Injury count:*

A total of 701 recorded medical issues resulted in absence from training or match play during the analysed 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.

(Figure 1)

*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 analysed 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 34822 (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).

(Figure 2)

*Injury frequency and incidence:*

Injury frequency, means and incidence rates per-1000 playing hours (p/1000h) 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/1000h.

(Figure 3)

*Nature of injuries:*

Most injuries occurred in the lower extremity (n=510, 85%). Traumatic injuries were more common than overuse injuries (n=439, 73% versus n=164, 27%), with muscle tears/strains/cramps (n=146, 36%), sprains (n=114, 26%) and haematoma/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 intable 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 (χ2 (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).

Subsequently, injury location was found to have a statistically significant (*p*<.001) association with the U’13 (χ2  (9, N = 64) = 50.0), U’18 (χ2  (11, N = 102) = 103.0) and U’21 (χ2  (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.

*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 haematoma/contusion (n=83, 14%). Between age-groups, statistically significant (χ2 (9) = 50.72, p<.001) differences in injury type were observed between U’13 - U’12 (*p* = 0.015*)* and U’21 - U’18 (*p* = 0.002*)*.

Subsequently, injury type was found to have a statistically significant (*p*<.001) association with the U’13 (χ2  (7, N = 64) = 53.7) and U’21 (χ2  (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)

*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/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.

*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*>0.05)

*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, whilst 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*>0.05).

(Figure 4).

Discussion

A total rate of time-loss injuries for all players (U’9-U’21) of 2.4 p/1000 hrs exposure was recorded. This rate was previously reported in a similar elite-youth level cohort study (Tears et al. 2018). This is despite not including the youngest age groups (U’9-U’11) where we observed a low summative rate (1.0 p/1000h), nor the eldest (U’21) which showed our highest rate (4.8 p/1000h).

Our study appears to be the first to detail injury rates specifically in elite-level U’9 (1.8 p/1000h) and U’10 (2 p/1000h) 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 minimise injury risk as rapid increases in exposure have been shown to exacerbate youth injury occurrence (Van der Sluis et al. 2014). 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 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 (Faude et al. 2013; Renshaw and Goodwin 2016; Read et al. 2018; Tears et al. 2018). Similarly, our injury location findings are comparable with the thigh, knee, ankle and hip/groin most frequently injured (Le Gall 2006; Renshaw et al. 2016; Read et al. 2018; Tears et al. 2018). Injury location and type are of course interrelated and, when analysing 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 (Ekstrand et al. 2016). Whilst thigh muscle injuries present a significant challenge for researchers and clinicians in adult football (Ekstrand et al. 2016), there may be added vulnerability in youth players due to incomplete muscle development whilst coping with large repetitive forces experienced with football movements (Price et al. 2004). These factors further coincide with less consideration for strength and conditioning regimes than their senior counterparts, which may play a protective role against injury (Wrigley et al. 2012). 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 (Le Gall et al. 2006; Read et al. 2018). 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 (Price et al. 2004), when physical adaptations increase stress on bone apophyses (Monasterio et al. 2020). 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 is warranted in players aged 12-13 years and appears 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 (Renshaw and Goodwin, 2016; Tears et al. 2018) and may be partially explained by increased changes to limb-length, mass and moments of inertia observed during periods of peak physical growth (Adirim & Cheng, 2003; Hawkins and Metheny, 2001). Such changes may impact physical characteristics such as muscle strength, where notable fluctuations may increase the risk of hip/groin injury (Engebretsen et al. 2010). 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 (Gabbe et al. 2010) and perhaps, therefore the key to reducing senior groin injury lies with increased attention and management of youth players (Light et al. 2018).

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 amongst academy players. Indeed, a previous study in elite U’14 footballers (Le Gall et al. 2007) 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. Whilst 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. (2007) found normal and late maturing players registered more severe and osteochondral related injuries, whilst 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 (Monasterio et al. 2020).

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 prioritising medical attention to players. Indeed, survey data by Light et al. (2018) 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% (Thorborg et al. 2017).

*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. Whilst 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, whilst we report ‘team-level’ exposure calculations based on ‘normal’ training and match schedules – this does not account for individual activities performed between sessions (e.g. 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 (Fig. 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 (Roche et al., 1981). The median error associated with this equation is 2.2 +/- 0.6 cm in males between 4.0 to 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 (Bahr et al. 2009), well highlighted in a recent study where time-loss measurement captured just 10% of groin problems in footballers (Esteve et al. 2020). 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.

*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.

References:

1. Faude O, Rößler R, Junge A. Football injuries in children and adolescent players: are there clues for prevention?. Sports Med. 2013;43(9):819-837
2. Read, P. J., Oliver, J. L., De Ste Croix, M. B., Myer, G. D., and Lloyd, R. S. (2018).An audit of injuries in six English professional soccer academies. J. Sports Sci. 36, 1542–1548.
3. Pfirrmann D, Herbst M, Ingelfinger P, Simon P, Tug S. Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review. J Athl Train. 2016;51(5):410-424. doi:10.4085/1062-6050-51.6.03
4. McCunn R, Gibson N, Hugh HK Fullagar H, Harper L. Professional youth football academy injury data: collection procedures, perceived value, and use, Sci Med Footb. 2018; , 2(2): 141-148
5. Le Gall F, Carling C, Reilly T, Vandewalle H, Church J, Rochcongar P. Incidence of injuries in elite French youth soccer players: a ten-season study. Am J Sports Med. 2006; 34:928–938.
6. Brownstein CG, Ball D, Micklewright D, Gibson NV. The Effect of Maturation on Performance During Repeated Sprints With Self-Selected Versus Standardized Recovery Intervals in Youth Footballers. Pediatr Exerc Sci. 2018;30(4):500-505
7. Johnson DM, Williams S, Bradley B, Sayer S, Murray Fisher J, Cumming S. Growing pains: Maturity associated variation in injury risk in academy football. Eur J Sport Sci. 2020;20(4):544-552
8. Le Gall F, Carling C, Reilly T. Biological maturity and injury in elite youth football. Scand J Med Sci Sports. 2007;17(5):564-572
9. van der Sluis A, Elferink-Gemser MT, Coelho-e-Silva MJ, Nijboer JA, Brink MS, Visscher C. Sport injuries aligned to peak height velocity in talented pubertal soccer players. Int J Sports Med. 2014;35(4):351-355
10. Palmer A, Fernquest S, Gimpel M, et al. Physical activity during adolescence and the development of cam morphology: a cross-sectional cohort study of 210 individuals. Br J Sports Med. 2018;52(9):601-610.
11. Renshaw A, Goodwin P. Injury incidence in a Premier League youth soccer academy using the consensus statement: a prospective cohort study. BMJ Open Sport Exerc Med. 2016;2(1)
12. Monasterio X, Gil S, Bidaurrazage-Letona I, Lekue J, Santisteban J, Diaz-Beitia G, Martin-Garetxana I, Bikandi E, Larruskain J. Injuries according to the percentage of adult height in an elite soccer academy. J Sci Med Sport. 2020; doi:https://doi.org/10.1016/j.jsams.2020.08.004
13. The Premier League. 2011. Elite player performance plan. [accessed

 2020 Jan 01] <https://www.goalreports.com/EPLPlan.pdf>.

1. Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. Br J Sports Med. 2011;45(7):553-558
2. Werner J, Hägglund M, Waldén M, Ekstrand J. UEFA injury study: a prospective study of hip and groin injuries in professional football over seven consecutive seasons. Br J Sports Med. 2009;43(13):1036-1040
3. Khamis HJ, Roche AF. Predicting adult stature without using skeletal age: the Khamis-Roche method [published correction appears in Pediatrics. 1995; 95(3):457
4. Malina RM, Rogol AD, Cumming SP, Coelho e Silva MJ, Figueiredo AJ. Biological maturation of youth athletes: assessment and implications. Br J Sports Med. 2015;49(13):852-859.
5. Cumming SP, Brown DJ, Mitchell S, et al. Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. J Sports Sci. 2018;36(7):757-765.
6. Phillips LH. Sports injury incidence. Br J Sports Med. 2000;34(2):133-136. doi:10.1136/bjsm.34.2.133
7. Sharpe D. Your Chi-Square Test is Statistically Significant: Now What?," Practical Assessment, Research, and Evaluation. 2015; 20 (8)
8. Tears C, Chesterton P, Wijnbergen M. The elite player performance plan: the impact of a new national youth development strategy on injury characteristics in a premier league football academy. J Sports Sci. 2018;36(19):2181-2188.
9. Ekstrand J, Waldén M, Hägglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. Br J Sports Med. 2016;50(12):731-737.
10. Price RJ, Hawkins RD, Hulse MA, Hodson A. The Football Association medical research programme: an audit of injuries in academy youth football. Br J Sports Med. 2004;38(4):466-471.
11. Wrigley R, Drust B, Stratton G, Scott M, Gregson W. Quantification of the typical weekly in-season training load in elite junior soccer players. J Sports Sci. 2012;30(15):1573-1580.
12. Le Gall F, Carling C, Reilly T. Biological maturity and injury in elite youth football. Scand J Med Sci Sports. 2007;17(5):564-572.
13. Adirim TA, Cheng TL. Overview of injuries in the young athlete. *Sports Med*. 2003;33(1):75-81.
14. Hawkins D, Metheny J. Overuse injuries in youth sports: biomechanical considerations. *Med Sci Sports Exerc*. 2001;33(10):1701-1707
15. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Intrinsic risk factors for groin injuries among male soccer players: a prospective cohort study. *Am J Sports Med*. 2010;38(10):2051-2057.
16. Gabbe BJ, Bailey M, Cook JL, et al. The association between hip and groin injuries in the elite junior football years and injuries sustained during elite senior competition. *Br J Sports Med*. 2010;44(11):799-802.
17. Light N, Smith N, Delahunt E, Thorborg K. Hip and groin injury management in English youth football: a survey of 64 professional academies. *Sci Med Footb*. 2018; 2 (2) 133-140,
18. Thorborg K, Krommes KK, Esteve E, et al. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *Br J Sports Med*. 2017,51:562-571
19. Roche, A. Growth, Maturation, and Body Composition: The Fels Longitudinal Study 1929–1991. 1992; Cambridge: Cambridge University Press
20. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. *Br J Sports Med*. 2009;43(13):966-972.
21. Esteve, E,  Clausen, MB,  Rathleff, MS, et al.  Prevalence and severity of groin problems in Spanish football: A prospective study beyond the time‐loss approach. *Scand J Med Sci Sports*. 2020; 30: 914– 921.

**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) |
| Haematoma/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 (e.g. 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<0.05)*

 † 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 analysed)

Figure legends:

**Figure 1**. Breakdown of injury records analysed, including age-group and player contributions.

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

**Figure 3**. Time-loss injury frequency (N) and incidence (p/1000h) per age-group, for all seasons analysed

**Figure 4.** The most common injuries sustained by U’13-U’16 aged players and their maturation status at time of injury occurrence

**Box 1**. Operational definitions