ORIGINAL ARTICLE

Maturation selection bias and injury in a secondary school sports academy

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ABSTRACT

The aim of this study was to examine maturation selection bias and injury in a secondary school sports academy. Male students (n=98) from a Boys High School had their anthropometric measurements taken (standing height and weight). Estimated percent of predicted adult height (%PAH) was derived using the Khamis-Roche method. Percent of PAH was used to estimate maturity status and timing. Participants also completed an injury history survey designed to record injuries experienced over the previous three months. Most participants were early maturers (65%, n=64), suggesting a bias towards the selection of more mature players. Late maturers accounted for only 1% (n=1) of players selected. Injury history identified that 60% (n=52) of participants had been injured in the three months prior to data collection but there was no association with maturity status. Increased awareness of the potential for maturity-based selection bias in secondary school team sports is needed.

INTRODUCTION

Youth sport is popular around the world and it is generally accepted, the primary reason younger children (ages 5-10 years) participate in sport is because it is fun, and they enjoy it.[40] However, as young children move towards and into adolescence, sporting goals and reasons for playing sport often change. While fun is still a factor, performance orientated goals relating to team selection and skill enhancement become more important.[14] In many environments sport team selection based on ability can occur at a very young age, with trials for premier teams beginning from as young as nine years old.[30]

It is generally acknowledged that in team selection during adolescence, coaches select players that possess greater physical capabilities and subsequently better athletic performance[28]. As a result, many authors have identified that biological maturation must be factored in when selecting youth for sports teams to avoid the potential for inappropriate early deselection of late maturers.[13,16,19] This can potentially result in talented young people not being retained in sport and/or late maturers dropping out because they are being told they are not good enough. This leads to an ineffective and inefficient selection system as better physical capabilities associated with more advanced biological maturation are known to have a minimal impact on performance differences once players fully mature.[9,11] Thus, an understanding of biological maturity status is important when selecting adolescents to ability-based sports teams. An awareness of maturational status is also important to help reduce injury risk. Injuries are a concern in youth sport as they can negatively impact sports participation and physical activity increasing the risk of chronic disease.[21] Previous research suggests there are periods of time during maturation where players are more susceptible to injury.[2] The highest rate of injuries has been reported during the period of peak height velocity (PHV), potentially due to rapid anthropometrical, neuromuscular, and structural changes.[7,15] Players circa-PHV (average age 12 years in girls and 14 years in boys) have been reported to experience the highest injury rate.[15] The severity and burden of injuries has also been shown to vary across maturation[7]. As the risk, severity and burden of injuries change across the stages of maturity, monitoring maturation allows training to be adapted to potentially reduce injury risk.[34] Maturity estimation based on anthropometric measurements used to estimate current percentage of predicted adult height (%PAH) is widely used in youth sport settings.[34]

To date there is little evidence in youth sport in New Zealand regarding potential maturity related selection bias in secondary school sport nor the association between maturity and injury history. Thus, the aims of this research were to investigate (i) the maturity status of players selected to a performance-based sport academy and (ii) the association between maturity and injury history.

METHODS

Participants

Ninety-eight males in school years 9 and 10 selected for premier youth sports teams at a boy's high school were recruited to participate in this study. Prior to participation, all participants and parents completed consent and assent forms as appropriate. Ethical approval was given for the study by the University Ethics Committee.

Biological Maturity Estimation

To estimate biological maturity status and timing, anthropometric data including standing height and weight was recorded for all participants. Height was measured with a stadiometer and weight with standard scales. Additionally, the participant's biological parents were asked to estimate their height. A previously published excel spreadsheet was used to estimate %PAH based on the Khamis Roche method.[37] Participants with a %PAH less than 88% were categorised as pre-PHV, between 88% and 93% circa-PHV and greater than 93% as post-PHV[8]. Maturity timing estimations were calculated by converting %PAH to standardised z-scores,[34] as has been reported previously.[13] Z-scores are derived from reference data reported in the longitudinal Berkley Growth Study.[5] Two criteria were used to estimate maturity timing. Participants with z-scores of -0.5 to +0.5 were categorised as on-time; a z-score greater than +0.5 was categorised as early and below -0.5 as late. A more conservative criterion was also applied where z-scores of -1.0 to +1.0 were categorised as on-time; a z-score greater than +1.0 was categorised as early and below -1.0 as late.

Injury data collection

A face-to-face paper-based questionnaire was used to capture injury history. The questionnaire was designed to capture injuries from youth participants and has been reported previously.[20] Participants were asked if they had sustained any sport-related injuries during the past 3 months. For every participant who answered yes, the researcher spoke to them and verified the location and type (acute or gradual onset) of each injury. Acute injuries were defined as a sudden pain that occurred as the result of an identifiable event. Gradual onset injuries were defined as any physical complaint not induced by a single sudden event and could include both overuse problems and growth-related problems. All injuries were recorded, whether time was lost from sport or not.

Data Analysis

Descriptive statistics were used to examine the extent of any selection bias towards early maturing players (proportion of participants in each category) and summarise the survey responses to the injury history questions (percentage of participants with an injury). A one-sample t-test was used to examine the degree to which biological maturation bias existed across the total sample by comparing the observed mean z-score value against the value expected for the general population (mean maturity z-score = 0.0). Results are presented as z-score mean difference and effect size (Cohens D ±95% confidence interval). Effect size magnitude was interpreted based on the following scale (small = 0.2–0.49; moderate = 0.5–0.79; large = 0.8–1.49; very large ≥ 1.5). Additionally, a Chi-square test was used to analyse the expected proportion of early, on-time and late maturers relative to what could be expected based on a normal distribution. Based on the most used criterion (z-score ±1.0), the expected frequency of early maturing players (z score > 1.0) and late maturing players (z score < 1.0), in a normally distributed population, would be 15.7 (16% of the 98 participants) and the expected frequency of on-time players would be 66.6 (68% of the 98 participants). Results are presented as observed vs expected frequency for maturity timing. Additionally, an independent samples t-test was used to compare mean height and weight between early and on-time/late maturers. Results are again presented as mean difference and 95% confidence interval. Finally, logistic regression was used to investigate the association between injury history and maturity status (pre, circa, post-PHV). Results are presented as unadjusted odd ratios with 95% confidence intervals. The threshold for statistical significance was set at $p < 0.05$.

RESULTS

Descriptive statistics identifying chronological age (CA) and %PAH z-score for all participants are reported in Table 1. The CA range was 13.0 to 15.2 years (mean 14.1 years). Estimated maturity status, expressed as %PAH, suggested participants on average were post-PHV (mean %PAH = 93.1%). Estimated maturity timing (%PAH expressed as z-scores) was significantly greater than expected in the general population (z-score mean difference effect size = 1.2, 95% CI = 0.93 to 1.4, p<0.05). Fifty seven percent of participants were post-PHV (Table 2) ranging from 21% (hockey) to 68% (basketball).

Based on the less conservative criterion (z-score ±0.5), 65% of participants were classified as early maturers, 34% on-time and 1% late, however this varied by age group (Table 3). The percentage of early maturers also varied by sport from a high of 89% (rowing) to a low of 29% (hockey). Applying the more commonly used but more conservative criterion (z-score ±1.0),

Table 1. Descriptive statistics for chronological age (CA), percentage of predicted adult height (%PAH), maturity timing (%PAH z-score)

Variables	**Mean ±SD**	**Range**
CA (yrs)	14.1 ± 0.6	13 – 15.2
% PAH	93.1 ± 3.2	85.8 – 101.4
% PAH z-score	0.7 ± 0.6*	-0.6 – 2.8

*significantly different from z=0.0

Table 2. Distribution of academy players by maturity status

	Maturity Status (%PAH)		
	Pre (<88%)	Circa (88 to 93%)	Post (>93%)
Full Sample (*n* = 98)	6.1 % (*n*=6)	36.7% (*n*=36)	57.2% (*n*=56)
Sport	**Pre (<88%)**	**Circa (88% to 93%)**	**Post (>93%)**
Basketball (*n* = 22)	0% (*n*=0)	31.8% (*n*=7)	68.2% (*n*=15)
Cricket (*n* = 7)	14.3% (*n*=1)	0 % (*n*=0)	85.7% (*n*=6)
Football (*n* = 24)	12.5% (*n*=3)	25% (*n*=6)	62.5% (*n*=15)
Hockey (*n* = 14)	7.2% (*n*=1)	71.4% (*n*=10)	21.4% (*n*=3)
Rowing (*n* = 18)	0% (*n*=0)	33.3% (*n*=6)	66.7% (*n*=12)
Rugby (*n* = 13)	15.4% (*n*=2)	46.1% (*n*=6)	38.5% (*n*=5)

Table 3. Distribution of academy players by maturity timing (z-score ±0.5)

Age Group	Late	Maturity Timing* On-time	Early
Full Sample (*n* = 98)	1.0% (*n*=1)	33.7% (*n*=33)	65.3% (*n*=64)
13-13.9 (*n* = 43)	2.3% (*n*=1)	46.5% (*n*=20)	51.2% (*n*=22)
14-14.9 (*n* = 46)	0% (*n*=0)	23.9% (*n*=11)	76.1% (*n*=35)
15-16 (*n* = 9)	0% (*n*=0)	22.2% (*n*=2)	77.8% (*n*=7)
Sport	**Late**	**On-time**	**Early**
Basketball (*n* = 22)	0% (*n*=0)	27.3% (*n*=6)	72.7% (*n*=16)
Cricket (*n* = 7)	0% (*n*=0)	28.6 % (*n*=2)	71.4 (*n*=5)
Football (*n* = 24)	4.2% (*n*=1)	29.2% (*n*=7)	66.6% (*n*=16)
Hockey (*n* = 14)	0% (*n*=0)	71.4% (*n*=10)	28.6% (*n*=4)
Rowing (*n* = 18)	0% (*n*=0)	11.1% (*n*=2)	88.9% (*n*=16)
Rugby (*n* = 13)	0% (*n*=0)	46.1% (*n*=6)	53.9% (*n*=7)

*On-time = z-score ±0.5, Late = z-score < 0.5, Early = z score >0.5

Table 4. Distribution of academy players by maturity timing (z-score ±1.0)

Age Group	Late	Maturity Timing* On-time	Early
Full Sample (*n* = 98)	0 % (*n*=0)	65.3% (*n*=64)	34.7% (*n*=34)
13-13.9 (*n* = 43)	0% (*n*=0)	62.8% (*n*=27)	37.2% (*n*=16)
14-14.9 (*n* = 46)	2.1% (*n*=1)	63.8% (*n*=30)	34.1% (*n*=16)
15-16 (*n* = 9)	0% (*n*=0)	77.8% (*n*=7)	22.2% (*n*=2)
Sport	**Late**	**On-time**	**Early**
Basketball (*n* = 22)	0% (*n*=0)	63.6% (*n*=14)	36.4% (*n*=8)
Cricket (*n* = 7)	0% (*n*=0)	85.7 % (*n*=6)	14.3% (*n*=1)
Football (*n* = 24)	0% (*n*=0)	66.7% (*n*=16)	33.3% (*n*=8)
Hockey (*n* = 14)	0% (*n*=0)	78.6% (*n*=11)	21.4% (*n*=3)
Rowing (*n* = 18)	0% (*n*=0)	38.9% (*n*=7)	61.1 % (*n*=11)
Rugby (*n* = 13)	0% (*n*=0)	76.9% (*n*=10)	23.1% (*n*=3)

*On-time = z-score ±1.0, Late = z-score < 1.0, Early = z score >1.0

Table 5. Relationship between injury history and maturity status

	Circa	Post	Unadjusted OR (95% CI)	P value
History any Injury (%)	58	61	1.16 (0.48 - 2.79)	0.74
History overuse Injury (%)	39	35	0.84 (0.34 - 2.04)	0.69
History acute injury (%)	19	26	1.56 (0.54 - 4.6)	0.41

35% of participants were classified as early, 65% on-time with no late maturers (Table 4). The percentage of early maturers again varied by sport from a high of 61% (rowing) to 14% (cricket). Results of the Chi-square analysis showed significantly more early maturers than expected (p<0.05), based on the more commonly used criterion (z-score ±1.0), (Table 4).

Eighty-seven participants provided information on their recent injury history with 60% (n=52) reporting an injury in the previous 3 months (38% acute injuries and 62% overuse injuries). The most common injury locations were the knee (29%) and ankle (17%). There was no significant association between injury history and maturity status (note pre-PHV not included in the injury analysis due to small n) (Table 5).

DISCUSSION

Findings from this study identified a bias towards more mature players in a school sports academy. Based on the criterion (z scores of ±0.5), this bias was stronger in the 14-year age group (76% early maturers) compared to the 13-year age group (51% early maturers). This is likely due to the older age, an additional year in the sport and boys advanced in maturity (early maturing) being selected in greater proportions. The average age of PHV in male youth is approximately 14 years of age.[1,18] This is also the period when more mature players dominate their less mature counterparts. Irrespective of the criterion used, the percentage of late maturing players did not exceed 1% of the whole sample, further suggesting a maturity-based selection bias.

Favouring more mature players in team selection is likely due to the increase in physical size and the associated enhanced performance capabilities. Better physical performance capabilities are common in more biologically mature youth athletes compared to less mature athletes of the same chronological age. For example, increased muscle mass seen in early maturers has been linked to greater strength, sprint, change of direction and jump performance.[12,19] However, these maturity-related enhancements do not continue into adulthood and may inappropriately result in less mature players being deselected.[39] Furthermore, sporting performance is not solely dictated by physical characteristics, but rather a combination of physical performance capability, technical competency, tactical awareness, and game understanding. Sports teams are at risk of losing late maturing players who, if retained, often compensate for reduced physical capability by developing more advanced technical, tactical and psychological skills compared to their more mature counterparts.[8]

The findings from the current study agree with previous studies that have also reported a maturity-based selection bias in youth sport.[13,16,19,27] Previous studies have reported that the 13 and 14 year age groups are dominated by more mature players (early maturers),[13,16] with maturity selection bias becoming more prominent in the age groups from 13 years of age onwards.[13] As several authors investigating elite football academies have suggested, the underrepresentation of late maturing and pre-PHV players in academy systems is a cause for concern[9]. As noted earlier later maturing players retained in the system often develop more advanced technical, tactical and psychological skills. The skill and knowledge gained during this period is thought to remain into adulthood whereas early maturing players' physical advantages subside.[9,11]

Maturity status classifications for the players in the current study (average age 14 years) further highlights the disproportionate representation of pre, circa and post-PHV players in the sport academy system. Post-PHV players accounted for 57.2% of the group followed by circa and pre-PHV players, 36.7% and 6.1% respectively. Given the average age of the players we might have expected more of the players to be circa-PHV and pre-PHV.

The current study investigated the potential maturity selection bias across a range of sports. Although formal comparisons weren't undertaken (due to small numbers), maturity status appeared to vary by sport with rowing and basketball having the highest proportion of early maturers. It has been reported previously that in a population of 868 Saskatchewan (Canadian) youth that some sports displayed a bias towards more mature players and some did not. In the 14-year age group hockey and basketball teams were observed to have a bias towards more mature players but this was not the case in soccer (football). These findings indicate that the physical sporting requirements of each sport can influence player selection due to perceived ability and maturity-related physical advantages. For example, elite youth rowers have been observed to be taller and heavier than sub-elite and reference populations,[41] with the stature of elite youth rowers similar to elite adult rowers.[6] Similarly, findings from the current study agree with a study of elite Portuguese football players.[19] Early maturing players were on average, taller (mean difference = 11.5cm; 95% CI = 8.0 to 14.9cm; p<0.001) and heavier (mean difference = 13.6 kg; 95% CI = 8.1 to 19.0kg; p<0.001) than the on-time/late maturing players. Observed and expected rowing ability is strongly associated with height and weight in youth elite rowers.[6] Maturity-related enhancements in field sports such as football and hockey aren't as strongly associated with team selection as rowing. This could be due to the sports having additional performance indicators such as sprint, COD and jumping ability as well as tactical game awareness.[3]

Although this study did not identify any clear association between maturity status and injury, our findings suggest that there is a considerable proportion of players circa-PHV (58%) and post-PHV (61%) who experienced injury within the three months prior to data collection. This contrasts previous research identifying that circa-PHV and on-time maturers experience a higher proportion of injuries compared to pre-PHV and late maturers[7]. Comparisons between studies are, however, difficult due to differences in the methods used to estimate maturity and to define injury. The high proportion of circa and post-PHV players injured in this study does raise concern as to whether the nature of the training and competition is appropriate for this period of development. Additionally, within the post-PHV cohort of players 26% experienced acute injuries. Acute injuries commonly result in extended periods of time loss where the players cannot train or compete to their full capacity.[32] Several researchers have observed increased injury rates and severity in academies and elite teams. Findings suggest that the more mature players experience injuries of greater trauma and severity at a higher rate than less mature players.[25]

There are several limitations to this study that readers need to be aware of. Firstly, the results are specific to a boy's high school academy system in the six key sports that had a recognised academy system within the school. Additionally given the differences in biological maturation for young females there is a need to investigate selection in secondary school female sport. The results may not be generalisable to other countries, schools, clubs, and academy systems. The methods used for the maturity estimation incorporated self-reported biological parent heights and the reference values used to estimate maturity status and derive z-scores were from European participants in America which may not be representative of the local population. Finally, injury history data was solely based on participant recall and although it was over a short time period (3 months) it is susceptible to recall bias.

CONCLUSION

There was a clear bias toward earlier maturing boys in this secondary school sports academy, with some indication this differed by sport. There were no clear associations between maturity status and recent history of injury, however a large proportion of this adolescent population reported some injury in the last 3 months. These findings suggest the need for selection processes that better acknowledge differences in maturity to avoid the loss of late maturing boys and the need to prioritise injury prevention in this adolescent group irrespective of maturity status.

REFERENCES

1. Aksglaede, L., Olsen, L. W., Sørensen, T. I., & Juul, A. (2008). Forty years trends in timing of pubertal growth spurt in 157,000 Danish school children. PloS one, 3(7), e2728. https://doi.org/10.1371/journal.pone.0002728
2. Bahr, R., & Krosshaug, T. (2005). Understanding injury mechanisms: a key component of preventing injuries in sport. British journal of sports medicine, 39(6), 324–329. https://doi.org/10.1136/bjsm.2005.018341
3. Bangsbo, J. (2014). Physiological demands of football. Sports Science Exchange, 27(125), 1-6.
4. Baxter-Jones, A., Barbour-Tuck, E. N., Dale, D., Sherar, L. B., Knight, C. J., Cumming, S. P., Ferguson, L. J., Kowalski, K. C., & Humbert, M. L. (2020). The role of growth and maturation during adolescence on team-selection and short-term sports participation. Annals of human biology, 47(4), 316–323. https://doi.org/10.1080/03014460.2019.1707870
5. Bayer, L. M., & Bayley, N. (1959). Growth diagnosis: Selected methods for interpreting and predicting development from one year. Chicago, IL: Chicago University Press.
6. Bourgois, J., Claessens, A. L., Vrijens, J., Philippaerts, R., Van Renterghem, B., Thomis, M., Janssens, M., Loos, R., & Lefevre, J. (2000). Anthropometric characteristics of elite male junior rowers. British journal of sports medicine, 34(3), 213–217. https://doi.org/10.1136/bjsm.34.3.213
7. Bult, H. J., Barendrecht, M., & Tak, I. (2018). Injury Risk and Injury Burden Are Related to Age Group and Peak Height Velocity Among Talented Male Youth Soccer Players. Orthopaedic journal

of sports medicine, 6(12), 2325967118811042. https://doi.org/10.1177/2325967118811042
8. Cumming, S., Lloyd, R., Oliver, J., Eisenmann, J., & Malina, R., (2017). Bio-banding in Sport: Applications to Competition, Talent Identification, and Strength and Conditioning of Youth Athletes. Strength and Conditioning Journal, 39(2), 34-47. https://doi.org/10.1519/SSC.0000000000000281
9. Cumming, S.P., Searle, C., Hemsley, J.K., Haswell, F., Edwards, H.J., Scott, S., Gross, A.S., Ryan, D., Lewis, J.A., White, P., Cain, A., Mitchell, S.B., & Malina, R.M. (2018). Biological maturation, relative age and self-regulation in male professional academy soccer players: A test of the underdog hypothesis. Psychology of Sport and Exercise, 39(2), 147–153. https://doi.org/10.1016/j.psychsport.2018.08.007
10. Figueiredo, A. J., Gonçalves, C. E., Coelho E Silva, M. J., & Malina, R. M. (2009). Characteristics of youth soccer players who drop out, persist or move up. Journal of sports sciences, 27(9), 883–891. https://doi.org/10.1080/02640410902946469
11. Gibbs, B. G., Jarvis, J. A., & Dufur, M. J. (2012). The rise of the underdog? The relative age effect reversal among Canadian-born NHL hockey players: A reply to Nolan and Howell. International Review for the Sociology of Sport, 47(5), 644–649. https://doi.org/10.1177/1012690211414343
12. Hammami, R., Chaouachi, A., Makhlouf, I., Granacher, U., & Behm, D. G. (2016). Associations Between Balance and Muscle Strength, Power Performance in Male Youth Athletes of Different Maturity Status. Pediatric exercise science, 28(4), 521–534. https://doi.org/10.1123/pes.2015-0231
13. Hill, M., Scott, S., Malina, R. M., McGee, D., & Cumming, S. P. (2020). Relative age and maturation selection biases in academy football. Journal of sports sciences, 38(11), 1359–1367. https://doi.org/10.1080/02640414.2019.1649524
14. Ingrell, J., Johnson, U. & Ivarsson, A. (2020). Achievement goals in youth sport and the influence of coaches, peers, and parents: A longitudinal study. Journal of Human Sport and Exercise, 15(3), 570-590. https://doi.org/10.14198/jhse.2020.153.09
15. Johnson, A., Doherty, P. J., & Freemont, A. (2009). Investigation of growth, development, and factors associated with injury in elite schoolboy footballers: prospective study. BMJ (Clinical research ed.), 338. https://doi.org/10.1136/bmj.b490
16. Johnson, A., Farooq, A. & Whiteley, R. (2017) Skeletal maturation status is more strongly associated with academy selection than birth quarter, Science and Medicine in Football, 1(2), 157-163, https://doi.org/10.1080/24733938.2017.1283434
17. Khamis, H. J., & Roche, A. F. (1994). Predicting adult stature without using skeletal age: the Khamis-Roche method. Pediatrics, 94(4 Pt 1), 504–507.
18. Malina, R. M., & Kozieł, S. M. (2014). Validation of maturity offset in a longitudinal sample of Polish boys. Journal of sports sciences, 32(5), 424–437. https://doi.org/10.1080/02640414.2013.828850
19. Malina, R. M., Peña Reyes, M. E., Eisenmann, J. C., Horta, L., Rodrigues, J., & Miller, R. (2000). Height, mass and skeletal maturity of elite Portuguese soccer players aged 11-16 years. Journal of sports sciences, 18(9), 685–693. https://doi.org/10.1080/02640410050120069
20. McGowan, J., Whatman, C., & Walters, S. (2020). The associations of early specialisation and sport volume with musculoskeletal injury in New Zealand children. Journal of science and medicine in sport, 23(2), 139–144. https://doi.org/10.1016/j.jsams.2019.09.002
21. McKay, C. D., Cumming, S. P., & Blake, T. (2019). Youth sport: Friend or Foe?. Best practice & research. Clinical rheumatology, 33(1), 141–157. https://doi.org/10.1016/j.berh.2019.01.017
22. Meylan, C., Cronin, J., Oliver, J., & Hughes, M. (2010). Talent Identification in Soccer: The Role of Maturity Status on Physical, Physiological and Technical Characteristics. International Journal of Sports Science & Coaching, 5(4), 571–592. https://doi.org/10.1260/1747-9541.5.4.571
23. Mirwald, R. L., Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. Medicine and science in sports and exercise, 34(4), 689–694. https://doi.org/10.1097/00005768-200204000-00020
24. Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. Journal of sports sciences, 21(7), 519–528. https://doi.org/10.1080/0264041031000071182
25. Monasterio, X., Gil, S. M., Bidaurrazaga-Letona, I., Lekue, J. A., Santisteban, J., Diaz-Beitia, G., Martin-Garetxana, I., Bikandi, E., & Larruskain, J. (2021). Injuries according to the percentage of adult height in an elite soccer academy. Journal of science and medicine in sport, 24(3), 218–223. https://doi.org/10.1016/j.jsams.2020.08.004
26. Myburgh, G. K., Cumming, S. P., Coelho E Silva, M., Cooke, K., & Malina, R. M. (2016). Growth and maturity status of elite British junior tennis players. Journal of sports sciences, 34(20), 1957–1964. https://doi.org/10.1080/02640414.2016.1149213
27. Ostojic, S. M., Castagna, C., Calleja-González, J., Jukic, I., Idrizovic, K., & Stojanovic, M. (2014). The biological age of 14-year-old boys and success in adult soccer: do early maturers predominate in the top-level game?. Research in sports medicine, 22(4), 398–407. https://doi.org/10.1080/15438627.2014.944303
28. Patel, R., Nevill, A., Cloak, R., Smith, T., & Wyon, M. (2019). Relative age, maturation, anthropometry and physical performance characteristics of players within an Elite Youth Football Academy. International Journal of Sports Science & Coaching, 14(3). https://doi.org/10.1177/1747954119879348.
29. Philippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., Craen, R., Bourgois, J., Vrijens, J., Beunen, G., & Malina, R. M. (2006). The relationship between peak height velocity and physical performance in youth soccer players. Journal of sports sciences, 24(3), 221–230. https://doi.org/10.1080/02640410500189371
30. Read, P. J., Oliver, J. L., De Ste Croix, M. B., Myer, G. D., & Lloyd, R. S. (2016). The scientific foundations and associated injury risks of early soccer specialisation. Journal of sports sciences, 34(24), 2295–2302. https://doi.org/10.1080/02640414.2016.1173221
31. Reilly, T., Williams, A., Nevill, A., & Franks, A. (2000). A multidisciplinary approach to talent identification in soccer. Journal of Sports Sciences, 18(9), 695–702. DOI: https://doi.org/10.1080/02640410050120078
32. Ritzer, E. E., Yang, J., Kistamgari, S., Collins, C. L., & Smith, G. A. (2021). An epidemiologic comparison of acute and overuse injuries in high school sports. Injury epidemiology, 8(1), 51. https://doi.org/10.1186/s40621-021-00344-8
33. Roche, A.F., Chumlea, W.C. and Thissen, D., (1988), Assessing the Skeletal Maturity of the Hand-Wrist: Fels Method. (Springfield: Charles C. Thomas). Or Chumela, W. C., Roche, A. F., & Thissen, D. (1989). The FELS method of assessing the skeletal maturity of the hand-wrist. American journal of human biology : the official journal of the Human Biology Council, 1(2), 175–183. https://doi.org/10.1002/ajhb.1310010206
34. Salter, J., De Ste Croix, M., Hughes, J. D., Weston, M., & Towlson, C. (2021). Monitoring Practices of Training Load and Biological Maturity in UK Soccer academies. International journal of sports physiology and performance, 16(3), 395–406. https://doi.org/10.1123/ijspp.2019-0624

35. Sherar, L. B., Baxter-Jones, A. D., Faulkner, R. A., & Russell, K. W. (2007). Do physical maturity and birth date predict talent in male youth ice hockey players?. Journal of sports sciences, 25(8), 879–886. https://doi.org/10.1080/02640410600908001
36. Toum, M., Tribolet, R., Watsford, M. L., & Fransen, J. (2020). The confounding effect of biological maturity on talent identification and selection within youth Australian football. Science & medicine in football, 5(4), 263–271. https://doi.org/10.1080/24733938.2020.1822540
37. Towlson, C., Salter, J., Ade, J. D., Enright, K., Harper, L. D., Page, R. M., & Malone, J. J. (2021). Maturity-associated considerations for training load, injury risk, and physical performance in youth soccer: One size does not fit all. Journal of sport and health science, 10(4), 403–412. https://doi.org/10.1016/j.jshs.2020.09.003
38. Tribolet, R., Bennett, K., Watsford, M. L., & Fransen, J. (2018). A multidimensional approach to talent identification and selection in high-level youth Australian Football players. Journal of sports sciences, 36(22), 2537–2543. https://doi.org/10.1080/02640414.2018.1468301
39. Vaeyens, R., Philippaerts, R., & Malina, R. (2005). The relative age effect in soccer: A match-related perspective. Journal of sports sciences. 23(7). 747-56. https://doi.org/10.1080/02640410400022052.
40. Visek, A. J., Achrati, S. M., Mannix, H., McDonnell, K., Harris, B. S., & DiPietro, L. (2015). The fun integration theory: toward sustaining children and adolescents sport participation. Journal of physical activity & health, 12(3), 424–433. https://doi.org/10.1123/jpah.2013-0180
41. Yoshiga, C. C., & Higuchi, M. (2003). Rowing performance of female and male rowers. Scandinavian journal of medicine & science in sports, 13(5), 317–321. https://doi.org/10.1034/j.1600-0838.2003.00321.x