The effect of maturation on children's experience of physical education: Lessons learned from academy sport.

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Abstract

Students' experiences of physical education (PE) are considered important for lifelong attitudes toward physical activity. Sex-related differences, and the individualised tempo in anthropometric growth because of biological maturation, leads to secondary school students within chronological age-ordered classes possessing vast differences in anthropometric and physical characteristics, which may negatively impact the PE experience for late- or early-maturing children. Therefore, the purpose of this review was to (i) critically discuss the influence of maturation on developmental factors related to PE and (ii) provide key stakeholders with guidance on how to manage this period of development more effectively and proposed solutions to alleviate the confounding influence of biological maturity currently being implemented within sporting contexts. Secondary school children of different maturation status are often categorised using arbitrary, chronological aged-ordered bandings, resulting in groups of children exhibiting large within-group variations in physical, behavioural, emotional, and educational development. This heterogeneity may lead to sub-optimal learning environments, which are confounded by complex and often negative developmental consequences for children who are at either extreme (late- and early-maturing) of the maturation continuum. This is particularly important within PE, where engagement, enjoyment and resultant lifelong physical activity attitudes are influenced by perceived competence and relatedness, and where these needs may be thwarted because of considerable maturity-related variations. This paper posits that it is time to for key stakeholders within child education to explore new ways to supplement current teaching practices and consider occasionally grouping children by maturation status (i.e. bio-banding) within secondary school PE to enhance students' experiences.

Keywords: Maturity, Physical Education, Adolescence, Psychosocial, Physical, Anthropometrical

Introduction

Most educational institutions group children by chronological age, with class membership determined by the child's date of birth and an arbitrary date threshold. In England, for example, children born between September 1st and August 31st in the following year are deemed to belong to a specific 'year group'. Membership within the year group determines when a child enters and exits the educational system and is typically maintained through primary (4-11 years) and secondary (11-16 years) school (see Figure 1). The practice of grouping pupils by age has been described as an 'implicit' rather than 'explicit' policy (Greenfield, 2011). That is, it is a policy that is founded upon the assumption that children of the same age are alike in terms of their physical, intellectual, and socio-emotional development and the need to implement some form of structural and organisation framework within the school system, rather than an unequivocal and/or identifiable source of evidence. Rather, it has been argued that conventional age grouping is the combined result of an accident of history, political ideology and professional inertia and that no formal policy exists in England which serves to prescribe how schools should be organised (Greenfield, 2011). However, it is widely accepted that children of the same age demonstrate marked variance in development (Malina et al., 1999; MacMaster et al., 2021), with some individuals progressing well in advance or delay of their same age peers (Cumming et al., 2012a; Cumming et al., 2008; Malina et al., 1999).

The idea of grouping children and/or designing a curriculum based upon an age-related developmental average has also been challenged on the basis that comparatively few children approximate the 'average' development standards for their age (Greenfield, 2011). Those children who are more advanced in maturation may be sub-optimally challenged when grouped relative to age, whereas those individuals who are delayed in maturation may experience too much challenge (Malina et al., 2019), adversely impacting their enjoyment of learning and perceptions of competence. This heterogeneity is particularly pertinent when looking at physical education (PE) in schools, where the student experience is critical for promoting lifelong physical activity (Kirk, 2005). For example, Lewis' (2014) interviews with children revealed that their perceived competence and physical aptitude were related to their engagement and enjoyment of PE. Understanding and improving the student experience of secondary school PE in the UK is more important now than ever before, with children's activity levels having fallen by 13% compared to pre-pandemic levels (Salway et al., 2022). It has also been reported that fewer than half of young people aged 5 to 18 in England (44.6%) are meeting basic physical activity guidelines (Sport England, 2021). Such confounding factors suggest that grouping children for PE classes is complex, with very few schools implementing the same approach across all year groups and formats of PE (Wilkinson and Penney, 2023a; Wilkinson and Penney, 2023b).

Children of the same age can vary by as much as 5-6 years in skeletal age, an established proxy of biological maturation in youth, leading to inherent (dis)advantages for early- and late-maturing adolescents (Malina et al., 2015). There is some evidence to suggest that students who feel they are at a lower level than others in their class may fear letting others down or being mocked by peers (Lewis, 2014). Such student insecurities perhaps demand the exploration of alternative means of grouping students within PE, rather than relying on chronological age, which may affect young people's perceived competence and ultimately negatively affect their attitudes and behaviours toward physical activity. The age groups system in sport is also founded upon the assumption that children of the same age share similar developmental attributes and interests, and the concept of grouping individuals around the 'average performer'. As is the case with school pupils, young athletes do, however, vary substantially in their development, with many individuals developing in advance or delay of their same age peers (Bolckmans et al., 2022; MacMaster et al., 2021; Malina et al., 1999). As such, sport and PE related environments have previously adopted ability matched grouping systems to account for the heterogeneity of adolescent groups, which has been shown to be an effective method to increase opportunities for success and physical activity for lower skilled students (Ward et al., 2019). In addition, many soccer academies have experimented with the idea of playing children ‘up’ or ‘down’ age categories to promote an enhanced playing environment (Kelly et al., 2021). Despite this, the confounding influence of sex (i.e. gender) (Wilkinson and Penney, 2023b) and variance in maturational status presents a significant challenge in the context of youth sport (Malina et al., 2019; Towlson et al., 2021c).

The timing of child maturation is highly individualised and non-linear (Philippaerts et al., 2006; Towlson et al., 2018), which may negatively impact engagement and the delivery of secondary school content to students who are early- or late-maturing. Students’ experiences of school PE form a foundation for lifelong physical activity behaviours. When considering the large variation in skeletal age for those within the same age group, alongside the additional differences in psychosocial, cognitive and behavioural maturation, it is important to consider the implications of continuing to group students by chronological age for PE in secondary schools. Therefore, the purpose of this review was to (i) critically discuss the influence of maturation on developmental factors related to PE in secondary schools and (ii) provide key stakeholders with guidance on how to manage this period of development more effectively and proposed solutions to alleviate the confounding influence of biological maturity currently being implemented within sporting contexts.

Biological maturation as a confounding factor for education systems

Biological maturation can be defined as the status, timing, and tempo of progress towards the adult state (Malina et al., 2015). The timing and development rate of growth are highly individual and asynchronous with chronological age across adolescence (Malina et al., 2004; Philippaerts et al., 2006) which can be measured and estimated using various methods (see

Sullivan et al. (2023) and Towlson et al. (2021c) for reviews of methods). Adolescent boys undergo an estimated phase of accelerated growth (approximately 7.5-9.7 cm/year) between 10.7-15.2 years (Philippaerts et al., 2006; Towlson et al., 2018) and girls approximately 7.0-10.0 cm/year, between 10.0-16.0 years (Malina et al., 2004) (see Figure 1). This sex-specific, enhanced tempo in growth is commonly referred to as peak height velocity (PHV) (Fransen et al., 2018; Kozieł and Malina, 2018; Malina et al., 2012; Mirwald et al., 2002). The PHV phase typically starts about two years earlier in girls than in boys (Malina et al., 2004), and boys continue to grow for another two years. These sex-related differences in timing and growth tempo offer an explanation as to why male students often end up being taller (approx. men >13 cm) than female students, despite achieving PHV later. This difference is likely caused by boys experiencing two additional years of pre-adolescent growth than girls (Malina et al., 2004). Such individualised and sex-related differences also manifest for peak weight velocity (PWV), where the onset of PWV occurs later than PHV, with peak body-mass gain (approximately 8.5kg/year [boys] and 10.0kg/year [girls]) occurring between 11.9-16.1 years in boys and 10.0-16 years in girls (Malina et al., 2004; Towlson et al., 2018). Given the sex-related differences and highly-individualised tempos in stature and body-mass growth, it is likely that students within chronological age-ordered school classes, spanning adolescence will be characterised as possessing vast within-class, maturity-related variations in anthropometric characteristics (body mass [~50%], stature [~29cm], fat-free mass [8.6kg] and predicted final adult height [10-15%]) (Hannon et al., 2020). Such within-class variations, largely dictated by differing maturity timing, mean that the onset of key maturational processes (i.e. PHV) can differ by three-four years between individuals of the same age (Hannon et al., 2020), which is evident if the student is either an early- (i.e. early onset of PHV) or late- (i.e. late-onset of PHV) maturing person. The individual timing of maturation is of significance to secondary education stakeholders, given that early-maturing students who are afforded early exposure to normative accelerations in growth will experience a lengthening of the legs relative to stature, a redistribution of subcutaneous adipose tissue (typically girls), and development of lean muscle-mass (typically boys) (Malina et al., 2004).

The timing of maturation (i.e. late and early) is of importance given that it has been shown to influence engagement in physical activity (Bacil et al., 2015; Baker et al., 2007; Barth Vedøy et al., 2020; Cumming et al., 2012a; Cumming et al., 2012b; Cumming et al., 2009; Drenowatz and Greier, 2019; Niven et al., 2009; Rodrigues et al., 2010), health (Costa e Silva et al., 2017; Cumming et al., 2011; van Lenthe et al., 1996), and psychosocial/behavioural (Andersson and Magnusson, 1990; Burnett et al., 2011; Celio et al., 2006; Fairclough and Ridgers, 2010; Magnusson et al., 1985; Sebastian et al., 2011) development of adolescents, which collectively can also impact a student's academic attainment (Burnett et al., 2011; Dubas et al., 1991; Roh and Kim, 2012). The highly-individualized phases of child growth and development (Malina et al., 2004; Philippaerts et al., 2006; Towlson et al., 2018) have been shown to confound academic development trajectories of some students (Burnett et al., 2011; Calthorpe et al., 2020; Dubas et al., 1991) and engagement in physical activity (Sherar et al., 2010), which in turn can influence academic performance (Rasberry et al., 2011). The influence of maturational status on students' educational experiences is thought to be multifaceted, where one variable alone is unlikely to offer adequate explanation for maturity-related variations in academic achievement.

One potential influencing factor of maturation status on academic achievement is achievement orientation (the belief about one's ability to achieve). A longitudinal study conducted by Dubas et al. (1991) on adolescent children indicated that late-maturing boys attained the lowest school achievement, with recent findings also suggesting that earlier pubertal timing in female adolescents might also be associated with an enhanced likelihood of risk-taking behaviours, coupled with an association between late age at menarche and lower education attainment (Calthorpe et al., 2020). Additionally, Roh and Kim (2012) have shown that breast development in girls, which can begin in pre-secondary school (56.5%), is a cause of student worry. Multifaceted findings such as these point to the need for more consideration of more complex, multifactorial influencing factors for academic performance, rather than (biological) age alone (Calthorpe et al., 2020). Therefore, the multifaceted effect of maturation on secondary school students as they navigate adolescence requires further multidisciplinary observational, interventional, and longitudinal examination.

Biological maturation as a confounding factor for students' experience of PE

Physical activity is associated with many benefits such as (but not limited to) improved aerobic fitness and decreased adiposity (Poitras et al., 2016), reduced depression and anxiety (Biddle and Asare, 2011), heightened self-esteem (Biddle and Asare, 2011) and improved academic performance (Lubans et al., 2018). Given that physical activity during childhood is vital for developing positive attitudes toward sport and exercise to sustain active lifestyles during adulthood (Daley, 2002), it is considered important to optimise student engagement and enjoyment in PE lessons, as the school environment is an obvious place to promote physical activity (Daley, 2002; Fairclough et al., 2002; Lewis, 2014). Indeed, positive PE experiences have been shown to contribute to positive attitudes towards physical activity in adulthood (Ladwig et al., 2018), despite 81% of students aged 11-17 being reported to be insufficiently active in 2016 (Guthold et al., 2020).

When exploring behaviour such as engaging in physical activity or PE, it is important to consider motivational processes, as motivation is said to predict intentional behaviours (Ryan and Deci, 2017). Self-Determination Theory (SDT) (Deci, 2008) differentiates types of motivation on a continuum, from amotivation (which reflects no motivation) to intrinsic motivation, where behaviours are engaged in due to an inherent interest or enjoyment (Ryan and Deci, 2017). In the context of PE, intrinsic motivation is positively associated with increased physical activity levels (Lonsdale et al., 2019) and adaptive outcomes such as intention to engage in physical activity and increased enjoyment (Vasconcellos et al., 2020). Extrinsic motivation, on the other hand, explains how behaviours can be performed for an external consequence (e.g. to avoid punishment, or a financial incentive); this type of motivation is associated with maladaptive outcomes such as boredom and negative affect (Vasconcellos et al., 2020). Nevertheless, Ntoumanis (2002) suggested that only a minority of pupils are intrinsically motivated to participate in PE, and a majority are either externally motivated or amotivated (do not take part). The SDT (Deci, 2008) also explains that there are three basic psychological needs which influence motivation for self-initiated behaviour (e.g. physical activity participation): autonomy (feelings of perceived control), competency (feeling a sense of mastery and an individual's sense that they can meet the demands of challenges) and relatedness (a universal desire to interact with, be connected to, and supported by others). The importance of these needs was supported in a study exploring students' perceptions of the activities they enjoyed and felt competent in (Lewis, 2014). The students who felt they were better at some sports than others typically attributed this opinion to their physical build or aptitude (e.g. bigger children felt better at strength sports).

Further highlighting the importance of a positive PE experience for students, Kerner et al. (2018) explain that PE lends itself to potential for social comparisons and body judgements between peers. Body image is explained to consist of both attitudinal, relating to satisfaction or dissatisfaction with body shape or size, and perceptual, relating to the estimation of body shape or size, components (Paap and Gardner, 2011). Body image disturbance has been defined as 'any form of affective, cognitive, behavioural or perceptual disturbance that is directly concerned with an aspect of physical appearance' (Thompson, 1995), and recent studies have highlighted an alarmingly high percentage of body dissatisfaction in boys (57%) and girls

(58%) (Dion et al. (2016). O'Donovan and Kirk (2008) explain that PE involves stimuli which could potentially provoke body image disturbance (e.g. changing rooms, PE kit, nature of the activity). Such disturbances are important to understand, as research has shown that body satisfaction is one of the most important contributing factors as to how students perceive PE (Kerner et al., 2018). Given that children of the same age can vary by up to six years in skeletal age (Malina et al., 2015), it might be suggested that grouping PE classes based on chronological age alone could have detrimental effects upon body satisfaction and engagement. Being in a class amongst peers who differ significantly in stature could impact an individual's motivation to participate in sport, their enjoyment during PE lessons, and perhaps ultimately limit future opportunities for engaging in sport and exercise in later life. This is a particularly important consideration when assessing the development of children at either extreme of the maturation continuum (i.e. late or early) (Cumming et al., 2017; Malina et al., 2019; Towlson et al., 2020) where large anthropometric (i.e. stature, body-mass) and physical (i.e. strength, speed, power) within-group differences can manifest (Hannon et al., 2020). These individuals may experience a reduced sense of relatedness and perceived competency (as predicted by SDT), which could increase body consciousness in adolescents due to maturity-related, emphasised differences in body development.

Biological maturation as a confounding factor for extra-curricular physical activity

The natural time course of biological maturation is strongly associated with natural anthropometric growth and physical development of adolescent children (Kozieł and Malina, 2018; Malina et al., 2004; Towlson et al., 2018), which can have an effect on physical activity engagement and health profiles of developing children (Bacil et al., 2015; Cumming et al., 2014; Cumming et al., 2011). Therefore, it may also be important to consider child maturation status and extra-curricular physical activity when developing the secondary school curriculum and assessing academic development trajectories, given that 51% of 251 examined studies evaluating physical activity and facets relating to academic attainment suggest positive associations between physical activity and academic performance (Rasberry et al., 2011). That said, 48% of the examined studies also showed no such associations (Rasberry et al., 2011), which suggests uncertainty regarding the association between physical activity involvement and academic performance, and which may be a binary phenomenon that warrants attention when developing the secondary school curriculum. In addition to this, maturity-associated consideration has been shown to affect sport participation at recreational (Baxter-Jones et al., 2020; Eisenmann et al., 2020) and development levels (Helsen et al., 2021b; Lovell et al., 2015; Towlson et al., 2017a; Towlson et al., 2018; Towlson et al., 2020) of sport. Specifically, late-maturing children have been shown to be disadvantaged due to (sub)conscious coach bias, where early-maturing boys are more likely to be selected for specialist coaching programmes (Lovell et al., 2015; Towlson et al., 2017b). Such selection bias for male students may well have a negative impact on late-maturing children's continued engagement in PE lessons and opportunity to participate in extracurricular sporting activities. However, such maturity-selection bias seems to be sex-specific, with Baxter-Jones et al. (2020) stating that it does not transcend female sport, with only ice hockey exhibiting a maturity selection bias. Such decision making may be due to a subconscious selection bias of teachers (and coaches) who select earlier maturing peers who possess temporary enhancements in anthropometric characteristics (e.g. advanced stature) which are seen as desirable in some team sports (e.g. soccer, netball, rugby) (Baxter-Jones et al., 2020).

In youth sport, coaches' perceptions of young athletes form an integral part of the talent identification process, where evaluations of player performances across games are important for determining a young player's future (Hill et al., 2020a). However, physical advantages associated with early-maturing adolescents can influence coaches' perceptions of talent (Cripps et al., 2016). Indeed, a study exploring coaches' perceptions of long-term potential in male soccer players aged under 16 (female data is unavailable) found that later-maturing players were perceived to have lower long-term potential than average- and early-maturing players (Cripps et al., 2016). Such expectations may in part be explained by either, or an interaction of, biological maturity status and relative age (i.e. the relative age of a person within a group categorised by arbitrary birth month cut-offs). These expectations may also be compounded by psychological phenomena such as Pygmalion effects (psychological phenomenon in which high expectations lead to improved performance), and Galatea effect (raising an individual's self-efficacy which results in an increase in performance) (Hancock et al., 2013). The critical impact of these expectations has also been reflected in early classroom-based studies (Rosenthal and Jacobson, 1968), where teachers' expectancies of students were manipulated by falsely labelling some students as "bloomers" following an intelligence quotient (IQ). Eight to 20 months later the labelled "bloomers" showed a greater increase in their IQ test score compared to the control condition. This phenomenon was explained by teachers changing their behaviour toward students which led to them changing their behaviour in response to these expectations (Rosenthal and Jacobson, 1968). Applying this work to extra-curricular sport, if teachers and coaches are more likely to pay attention to and select earlier-maturing peers due to their enhanced, temporary maturity-related characteristics, later-maturing peers will not only receive less objective opportunity for participating in extra-curricular sport, but their relatedness and perceived competence needs may be thwarted, reducing motivation toward and likelihood of engaging in sport in the future.

Sex-related differences on the effects of maturation status on physical activity

It is understood that secondary school aged males engage more in strenuous forms of exercise and total exercise behaviour than females (Cumming et al., 2011; Rodrigues et al., 2010). However, the timing of maturation (i.e. early or late) has been shown to have a mediating effect on adolescent engagement in physical activity (Bacil et al., 2015; Drenowatz and Greier, 2019; Garcia et al., 2018; van Lenthe et al., 1996). There is also evidence to suggest sex-related differences in exercise behaviour owing to maturation status (Cumming et al., 2008). A systematic review conducted by Bacil et al. (2015) highlighted some sex-related differences on the impact of maturation status for sedentary behaviour amongst girls and boys. They explain that where boys with advanced maturation were more involved in physical activity, conversely, girls who matured early had a lower level of physical activity. Indeed, boys who matured later appeared to be at a greater risk for excess weight gain, which can negatively affect the development of motor competence during early-adolescence (Drenowatz and Greier, 2019). In adolescent females, early-maturation is associated with less involvement in physical activity, with perceptions of attractiveness and sport competence being found to partially mediate relations between maturity status and physical self-worth (Cumming et al., 2011). This evidence points to the potential for maturity-specific curricular or interventions to enhance physical activity engagement. Such sex-related differences may in part be explained by maturation status influencing the self-perception of physical well-being, mood, and emotion. Specifically, early-maturing girls may possess morphological characteristics (size, shape, and body composition) that are not in accordance with social expectations of their peers. Celio et al. (2006) explains that early-maturing girls' willingness to participate in 'deviant' peer activities may increase, due to having greater contact with early-maturing (and often older) girls whom they feel most comfortable with. Therefore, matching girls for maturation status may need to be considered with caution.

In contrast, Jones and Crawford (2005) indicated that weight and muscularity anxieties had unique contributions to body dissatisfaction in adolescent boys. Weight concern was associated with higher body-mass index (BMI) and heightened frequency of conversations regarding appearance, whereas muscularity and muscle-building concerns were prevalent in boys who reported having lower BMI and were older. In contrast to the research surrounding adolescent females, early-maturing boys who possess enhanced anthropometrical characteristics (stature/body-mass) experience positive self-perception of physical well-being, moods and emotions due to their physique being more aligned with social expectations for boys (Cohane and Pope Jr., 2001; Jones and Crawford, 2005; Ricciardelli et al., 2000). This notion is also supported by Fairclough and Ridgers (2010), who revealed significant interactions between sex and maturity status in school children. They too found that boys' (approx. 10 years) physical self-perceptions improved with advancing maturity status, whereas girls' self-perceptions decreased (Fairclough and Ridgers, 2010). Findings also revealed between-sex differences in engagement in moderate-to-vigorous physical activity and that some domains of physical self-perceptions were attenuated when maturity status was controlled for (Fairclough and Ridgers, 2010). These results show potential for taking a sex and maturity-specific approach to future secondary education research which could offer plausible solutions to negate the confounding influence of maturation on engagement in physical activity. Despite some uncertainty regarding sex-related differences for the affect of maturation on physical activity engagement, it is clear that the timing of biological maturation appears to effect (positively and negatively) secondary school childrens' physical activity engagement. However, it is acknowledged that the causal reasons are multifaceted and complex (Moore et al., 2020).

Biological maturation as a confounding factor for psychosocial development in adolescents

Understanding the influence that maturation can have on the development of sex-specific, maturity-related psychosocial behaviours across adolescence (particularly in early- and late-maturing children) is of relevance to teachers, coaches, and guardians. Of course, awareness of such maturity-related developmental issues relating to psychosocial and cognitive behaviours in adolescence is not new. Over three decades ago Andersson and Magnusson (1990) stated the potential dangers of using chronological age (used in secondary schools) as the only reference point for judging whether or not a particular behaviour is a ‘risk’, especially when focusing on individual behaviours in adolescence. The authors also argued that certain behaviours (e.g. alcohol consumption) may manifest within very different biological and psychosocial maturity contexts. For instance, what might seem to be considered a "normal" adolescent behaviour (e.g. sexual relationships) for one individual (i.e. early-maturing), may well be considered relatively unknown for their age-peer (i.e. late-maturing), if biological or psychosocial maturation are not considered. The mechanism that underpins the desire for an adolescent to alter their behaviour is relatively unknown. A review by Blakemore and Choudhury (2006) proposes that changes in brain structure may continue across adolescence and earl-adulthood, suggesting that adolescents undergo a period of synaptic reorganisation and/or continued development during puberty which may enhance the brain`s sensitivity to function and social cognition input. Blakemore and Choudhury (2006) also suggest that this period may be similar to the sensitive periods of brain development that are evident in critical stages of growth such during early-childhood. Such sensitive periods arguably make secondary school aged children susceptible to peer pressure and more likely to conform to social norms within-groups.

Functional neuroimaging studies have found that ‘social brain’ regions in adolescent children may respond to rejection differently (Sebastian et al. (2011). This response is of relevance as such methods may permit future research studies to examine neural bases of responses to social rejection, which is of particular importance for adolescents and young adults given the highly-individualised timing of maturation of regions subserving emotional control and self-evaluative processing during social rejection (Sebastian et al., 2011). Therefore, it is imperative for prospective study designs to investigate the extent to which individual differences during periods of rejection and disappointment may affect adolescents' sense of relatedness and perceived competence, in the context of sport and exercise within and outside of the curriculum. Such issues are particularly relevant for future study design, considering that early- or late-maturing students may compare themselves to their peers due to significant differences in their anthropometric and physical characteristics, their individual experience of rejection (e.g. not being passed to in team sport, not being picked for the team by their coach), or even be subjected to bullying. Research focussed on matters associated with pubertal timing (i.e. early- or late-maturing), which has the potential to produce direct benefits and increased awareness of the underlying mechanisms of maturity timing, is vital for understanding the unique developmental challenges faced by children (Mendle et al., 2007).

Summary of the problem

The timing (early or late) of maturation affects physical activity engagement (Bacil et al., 2015; Barth Vedøy et al., 2020; Cumming et al., 2014; Cumming et al., 2012b) and psychological (Andersson and Magnusson, 1990; Burnett et al., 2011; Celio et al., 2006; Fairclough and Ridgers, 2010; Garcia et al., 2018; Sebastian et al., 2011) development of secondary school aged children. All of which collectively can impact a student's academic attainment (Burnett et al., 2011; Dubas et al., 1991; Roh and Kim, 2012), which is also influenced by the effect of maturation on the development of these characteristics across adolescence likely being sex-specific (Bacil et al., 2015; Baker et al., 2007; Cumming et al., 2008; Drenowatz and Greier, 2019; Rodrigues et al., 2010), and the magnitude of effect being mediated by whether the individual is late- or early-maturing. For instance, male adolescents engage in more strenuous forms of exercise and total exercise behaviour than females (Cumming et al., 2008; Cumming et al., 2011; Rodrigues et al., 2010), with the timing of maturation (i.e. early- or late-maturing) shown to have a mediating effect on adolescent engagement in physical activity (Bacil et al., 2015; Drenowatz and Greier, 2019; Garcia et al., 2018; van Lenthe et al., 1996) and perceptions of attractiveness (Cumming et al., 2008). However, sport competence is shown to partially mediate relations between maturity status and physical self-worth (Cumming et al., 2008). Such evidence might in part be explained by early-maturing girls possessing morphological characteristics (size, shape, and body composition) that may not be in accordance with social expectations (Garcia et al., 2018), which facilitates the formation of negative self-opinion and emotion. However, it may also be that male students experience contrasting effects of early-maturation. Therefore, it is possible that early-maturing boys, who experience PHV earlier than their peers, will be taller and have enhanced body-mass (Towlson et al., 2018; Towlson et al., 2020). In addition, it is also plausible to suggest that they will perceive such biological developments more positively in comparison to their early-maturing female counterparts as earlier-maturing and older boys have reported more frequent muscle-building conversations and had lower BMIs (Jones and Crawford, 2005). Founded on research-based observations, it is also intuitive to suggest that late-maturing boys and girls will likely experience contrasting effects of maturation in comparison to their early-maturing peers, and the effect of maturation on key areas of child development may impact willingness to engage in PE, lifelong attitudes toward physical activity and individual academic progress.

Lessons learnt from within a sport context

Despite evidence to suggest the effect of early- and late-maturation on various facets of child development (Bacil et al., 2015; Barth Vedøy et al., 2020; Cumming et al., 2014; Cumming et al., 2012b; Costa e Silva et al., 2017; Knowles et al., 2009; Niven et al., 2009), there have been few studies within education and child development contexts which have explored interventions which control for maturity status (Kelley et al., 2015). This oversight is surprising given the recommendation by Baxter-Jones et al. (2005) that paediatric researchers must include an assessment of biological age in study designs so that the confounding effects of maturation can be controlled for. Despite a paucity of education-based research, the effect of maturation on physical activity (Cumming et al., 2014; Cumming et al., 2012a; Cumming et al., 2012b; Cumming et al., 2008; Cumming et al., 2009; Cumming et al., 2011) and the over-selection of early-maturing children who are characterised as possessing advanced anthropometric and physical fitness characteristics due to early-PHV exposure for sports coaching programmes has been well-documented (Cumming et al., 2014; Helsen et al., 2021a; Lovell et al., 2015; Malina et al., 2020; Malina et al., 2015; Towlson et al., 2017b; Towlson et al., 2018). This maturity phenomenon results in the chronic under-selection of late-maturing children in team sport who likely possess the potential to develop equal technical and physical abilities as their early-maturing counterparts. Recognizing this problem, sporting organisations have explored the implementation of maturity status bio-banding (Barrett et al., 2022; Bradley et al., 2019; Cumming et al., 2018a; Lüdin et al., 2022; MacMaster et al., 2021; Romann et al., 2020; Towlson et al., 2021a; Towlson et al., 2022; Towlson et al., 2021b).

Bio-banding is the categorisation of children according to their biological maturity status, which can be achieved by measures of skeletal age via x-rays or using validated and reliable somatic, estimation equations. Bio-banding has been used across professional soccer organisations to enhance the physical, technical, tactical and psychosocial development of adolescent players (Towlson et al., 2023). The growing popularity of this approach is evidenced by a recent finding that 80% of 31 participating academies have used, or are currently using, bio-banding within their player development programmes (Towlson et al., 2023). This is accompanied by evidence which states that academy practitioners perceive bio-banding to enhance their ability to assess academy soccer players' talent (Towlson et al., 2023). The authors also suggest that practitioners who have used bio-banding believe that the method is an effective way of enhancing the perception of challenge, thereby providing a number of psychosocial benefits (Towlson et al., 2023). Academy soccer-based research has suggested that matching children for maturation has removed the anthropometric and physical fitness differences between them (MacMaster et al., 2021) and that bio-banded children perceive this change in categorisation as more equitable in terms of exertion during physical activity (Barrett et al., 2022), and that it results in a more positive experience (Bradley et al., 2019; Cumming et al., 2018a).

In addition to matching children for maturity status, purposefully mis-matching children (e.g. late- vs early-maturers) during bio-banded sessions might also provide late-maturing children with enhanced conditions that will allow them to demonstrate a number of important psychological and behavioural characteristics (Towlson et al., 2021b), which their 'normal' chronological age-ordered playing environment does not naturally afford them. For example, when performing in maturity mis-matched bio-banded soccer matches, later-maturing players have demonstrated a number of enhanced and highly desirable psychological characteristics (i.e. positive attitude, confidence, competitiveness) compared to their peers within age-categorised teams (Towlson et al., 2021b). The latter evidence suggests that prescribing a more challenging (but safe) playing environment than what players are typically habituated to may elicit positive performance and developmental benefits. Such potential enhancements in psychological and behavioural characteristics during mis-matched physical activity sessions may be partially explained by the 'underdog hypothesis' (Cumming et al., 2018b; Gibbs et al., 2012), which postulates that late-maturing children develop superior psychological skills that enable them to perform equally with their more mature counterparts (Gibbs et al., 2012). More specifically, it could be suggested that late-maturing children possess more advanced self-regulatory skills, which represent the extent to which individuals are metacognitively, motivationally, and behaviourally proactive participants in their learning process (Zimmerman, 2006). For instance, children who are mis-matched in one capacity (e.g. size, speed) must search for alternative strategies (e.g. anticipation, decision making) which allow them to compete. With appropriate levels of challenge and support, mis-matched sessions may be one means by which such desirable characteristics are encouraged and developed. This developmental phenomenon is important for secondary education stakeholders, because enhancing self-regulatory skills has been found to differentiate experts from their less-skilled counterparts (Toering et al., 2012), have lasting improvements on child academic attainment (Schunk et al., 2022), and may provide further insight relating to child PE development trajectories.

Bio-banding is also suggested to be an effective pedagogical tool within mixed-aged classrooms, with bio-banding being used to benefit both early- and late-maturing children during the delivery of psychological classroom-based sessions (Hill et al., 2020b). These have been shown to permit enhanced learning and development experiences for children at both ends of the maturity spectrum (Hill et al., 2020b). Although the traditional sporting and education contexts are different (i.e. training ground vs classroom), the demographic populations within these two examples are the same (i.e. secondary school aged). Both contexts comprise children of different maturation status, who are categorised using arbitrary, chronological aged-ordered bandings, resulting in groups of children exhibiting large within-group variations in development (Cumming et al., 2012a; Cumming et al., 2011; Malina et al., 1999). Such variations might create sub-optimal secondary school learning environments, which are confounded by the complex and often negative development consequences for children who are at either extreme (late- and early-maturing) of the maturation continuum. Therefore, is it now time for teachers and researchers to purposefully consider the timings and confounding implications of maturation on academic, psychosocial, and physical development of children (see Figure 1), and explore new, supplementary methods to group children within secondary school PE? If so, teachers and researchers may wish to consider new and innovative methods which negate the potentially detrimental effects of (early/late) maturation status on the student experience and reduce the negative consequences of standing out in a crowd. Unfortunately, however, no study investigating the efficacy of bio-banding within PE currently exists. We conclude this paper with suggestions for next steps to be taken by key stakeholders to permit further consideration, flexibility and engagement in understanding, recognising and removing the considerable effects that maturity status can have on adolescent physical activity and sport involvement. Our literature-informed suggestions for education key stakeholders are five-fold:

1) To ensure that all school stakeholders (teachers, students and parents) are well-informed regarding the highly variable influence of biological maturation on student development.

2) To adopt an openminded and flexible approach to teaching and curriculum design by considering alternative approaches to alleviate the temporary, maturity-related (dis)advantages afforded to late- and early-developing children during lessons in order to create fairer and more equitable learning environments.

3) To ensure that all members of staff are trained and fully understand the methodological considerations when assessing biological maturation (Towlson et al., 2021c).

4) To critically evaluate current school practices to understand how and when (girls: 10 to 13 years; boys 12 to 14 years [see Figure 1]) maturity matched (i.e. bio-banded) taught sessions can be achieved. Such sessions may involve extracurricular sessions which are comprised of maturity-matched students within one year group or transcend multiple year groups (e.g. bio-banded sports day events, bio-banded personal, social, health and economic education etc).

5) To understand that bio-banding does not involve categorising children based on their body size or shape. Instead, bio-banding is the categorisation of children according to their biological maturity status, which can be achieved by measures of skeletal age via x-rays or using validated and reliable somatic, estimation equations (appropriate for secondary school environments). The maturity estimation equations (See Mirwald et al. (2002), Moore et al. (2020), Fransen et al. (2018) and Kozieł and Malina (2018)) require only measures of stature and body-mass (some equations require parental mid-height) which are used to estimate either the age in which the child will undergo PHV or the percentage of final adult height the child has currently attained (Sullivan et al., 2023) using simple, validated equations (see Towlson et al. (2021c)) . It is this information alone which is used to bio-band children and not body type, shape or size.

We recognise the practical challenges (e.g. scheduling disruption) and ethical concerns (e.g. disrupting friendship groups) that key stakeholders may have when considering implementing bio-banding. Teachers will need to explain to children that they are not being categorised on the basis of physical characteristics but rather in an effort to increase inclusion, equity, and the challenges afforded by PE lessons. We recommend that teachers explain to parents, caregivers, and children the rationale for using bio-banding and the various psychological, social and motor benefits that might be derived from this approach. Furthermore, it is important to note that we are not advocating that bio-banding should replace chronological aged-ordered class design nor are we suggesting that bio-banding will inevitably benefit all children within PE settings. We are recommending a more openminded approach whereby stakeholders introduce bio-banding at opportune moments of the academic year (perhaps during science [i.e. biology], personal, social, health and economic education [PSHE] and PE lessons) based on an understanding of their students' physical, technical, motor, and psychological development. Whilst there are challenges with the implementation of bio-banding, we have highlighted a growing body of evidence which suggests that this approach can have a positive impact on adolescents' enjoyment of sport and their psychosocial development (Bradley et al., 2019; Cumming et al., 2018a). On the basis of such findings, we encourage educational researchers to explore the efficacy of bio-banded sessions given the promise they hold in creating equitable learning environments in which children might flourish.

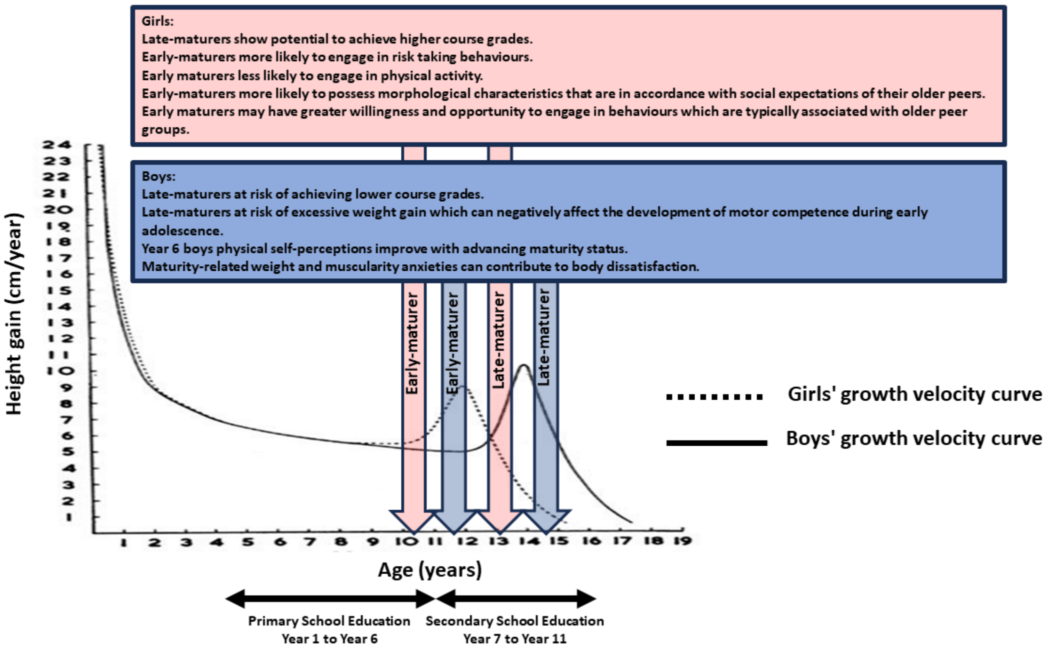

Figure 1. A summary figure adapted from Malina et al. (2004) to illustrate the annual growth rate in height (cm/year) accompanied by suggested maturity-related considerations for educators and coaches working with adolescent boys and girls.

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