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

For publication in:

European Physical Education Review

Christopher Towlson¹, Sean Cumming², Kate Donnan¹ and John Toner¹

Affiliations:

¹Department of Sport, Health and Exercise Science, University of Hull, UK

²Department for Health, University of Bath, Bath, UK

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23 **Abstract**

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

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49 **Keywords:** Maturity, Physical Education, Adolescence, Psychosocial, Physical,

50 Anthropometrical

51 Introduction

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

69 The idea of grouping children and/or designing a curriculum based upon an age-related
70 developmental average has also been challenged on the basis that comparatively few children
71 approximate the 'average' development standards for their age (Greenfield, 2011). Those
72 children who are more advanced in maturation may be sub-optimally challenged when grouped
73 relative to age, whereas those individuals who are delayed in maturation may experience too
74 much challenge (Malina et al., 2019), adversely impacting their enjoyment of learning and
75 perceptions of competence. This heterogeneity is particularly pertinent when looking at

76 physical education (PE) in schools, where the student experience is critical for promoting
77 lifelong physical activity (Kirk, 2005). For example, Lewis' (2014) interviews with children
78 revealed that their perceived competence and physical aptitude were related to their
79 engagement and enjoyment of PE. Understanding and improving the student experience of
80 secondary school PE in the UK is more important now than ever before, with children's activity
81 levels having fallen by 13% compared to pre-pandemic levels (Salway et al., 2022). It has also
82 been reported that fewer than half of young people aged 5 to 18 in England (44.6%) are meeting
83 basic physical activity guidelines (Sport England, 2021). Such confounding factors suggest
84 that grouping children for PE classes is complex, with very few schools implementing the same
85 approach across all year groups and formats of PE (Wilkinson and Penney, 2023a; Wilkinson
86 and Penney, 2023b).

87 Children of the same age can vary by as much as 5-6 years in skeletal age, an established
88 proxy of biological maturation in youth, leading to inherent (dis)advantages for early- and late-
89 maturing adolescents (Malina et al., 2015). There is some evidence to suggest that students
90 who feel they are at a lower level than others in their class may fear letting others down or
91 being mocked by peers (Lewis, 2014). Such student insecurities perhaps demand the
92 exploration of alternative means of grouping students within PE, rather than relying on
93 chronological age, which may affect young people's perceived competence and ultimately
94 negatively affect their attitudes and behaviours toward physical activity. The age groups
95 system in sport is also founded upon the assumption that children of the same age share similar
96 developmental attributes and interests, and the concept of grouping individuals around the
97 'average performer'. As is the case with school pupils, young athletes do, however, vary
98 substantially in their development, with many individuals developing in advance or delay of
99 their same age peers (Bolckmans et al., 2022; MacMaster et al., 2021; Malina et al., 1999). As
100 such, sport and PE related environments have previously adopted ability matched grouping

101 systems to account for the heterogeneity of adolescent groups, which has been shown to be an
102 effective method to increase opportunities for success and physical activity for lower skilled
103 students (Ward et al., 2019). In addition, many soccer academies have experimented with the
104 idea of playing children ‘up’ or ‘down’ age categories to promote an enhanced playing
105 environment (Kelly et al., 2021). Despite this, the confounding influence of sex (i.e. gender)
106 (Wilkinson and Penney, 2023b) and variance in maturational status presents a significant
107 challenge in the context of youth sport (Malina et al., 2019; Towlson et al., 2021c).

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

120

121 **Biological maturation as a confounding factor for education systems**

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

126 Sullivan et al. (2023) and Towlson et al. (2021c) for reviews of methods). Adolescent boys
127 undergo an estimated phase of accelerated growth (approximately 7.5-9.7 cm/year) between
128 10.7-15.2 years (Philippaerts et al., 2006; Towlson et al., 2018) and girls approximately 7.0-
129 10.0 cm/year, between 10.0-16.0 years (Malina et al., 2004) (see Figure 1). This sex-specific,
130 enhanced tempo in growth is commonly referred to as peak height velocity (PHV) (Fransen et
131 al., 2018; Kozieł and Malina, 2018; Malina et al., 2012; Mirwald et al., 2002). The PHV phase
132 typically starts about two years earlier in girls than in boys (Malina et al., 2004), and boys
133 continue to grow for another two years. These sex-related differences in timing and growth
134 tempo offer an explanation as to why male students often end up being taller (approx. men >13
135 cm) than female students, despite achieving PHV later. This difference is likely caused by boys
136 experiencing two additional years of pre-adolescent growth than girls (Malina et al., 2004).
137 Such individualised and sex-related differences also manifest for peak weight velocity (PWV),
138 where the onset of PWV occurs later than PHV, with peak body-mass gain (approximately
139 8.5kg/year [boys] and 10.0kg/year [girls]) occurring between 11.9-16.1 years in boys and 10.0-
140 16 years in girls (Malina et al., 2004; Towlson et al., 2018). Given the sex-related differences
141 and highly-individualised tempos in stature and body-mass growth, it is likely that students
142 within chronological age-ordered school classes, spanning adolescence will be characterised
143 as possessing vast within-class, maturity-related variations in anthropometric characteristics
144 (body mass [~50%], stature [~29cm], fat-free mass [8.6kg] and predicted final adult height [10-
145 15%]) (Hannon et al., 2020). Such within-class variations, largely dictated by differing
146 maturity timing, mean that the onset of key maturational processes (i.e. PHV) can differ by
147 three-four years between individuals of the same age (Hannon et al., 2020), which is evident if
148 the student is either an early- (i.e. early onset of PHV) or late- (i.e. late-onset of PHV) maturing
149 person. The individual timing of maturation is of significance to secondary education
150 stakeholders, given that early-maturing students who are afforded early exposure to normative

151 accelerations in growth will experience a lengthening of the legs relative to stature, a
152 redistribution of subcutaneous adipose tissue (typically girls), and development of lean muscle-
153 mass (typically boys) (Malina et al., 2004).

154 The timing of maturation (i.e. late and early) is of importance given that it has been
155 shown to influence engagement in physical activity (Bacil et al., 2015; Baker et al., 2007; Barth
156 Vedøy et al., 2020; Cumming et al., 2012a; Cumming et al., 2012b; Cumming et al., 2009;
157 Drenowatz and Greier, 2019; Niven et al., 2009; Rodrigues et al., 2010), health (Costa e Silva
158 et al., 2017; Cumming et al., 2011; van Lenthe et al., 1996), and psychosocial/behavioural
159 (Andersson and Magnusson, 1990; Burnett et al., 2011; Celio et al., 2006; Fairclough and
160 Ridgers, 2010; Magnusson et al., 1985; Sebastian et al., 2011) development of adolescents,
161 which collectively can also impact a student's academic attainment (Burnett et al., 2011; Dubas
162 et al., 1991; Roh and Kim, 2012). The highly-individualized phases of child growth and
163 development (Malina et al., 2004; Philippaerts et al., 2006; Towlson et al., 2018) have been
164 shown to confound academic development trajectories of some students (Burnett et al., 2011;
165 Calthorpe et al., 2020; Dubas et al., 1991) and engagement in physical activity (Sherar et al.,
166 2010), which in turn can influence academic performance (Rasberry et al., 2011). The influence
167 of maturational status on students' educational experiences is thought to be multifaceted, where
168 one variable alone is unlikely to offer adequate explanation for maturity-related variations in
169 academic achievement.

170 One potential influencing factor of maturation status on academic achievement is
171 achievement orientation (the belief about one's ability to achieve). A longitudinal study
172 conducted by Dubas et al. (1991) on adolescent children indicated that late-maturing boys
173 attained the lowest school achievement, with recent findings also suggesting that earlier
174 pubertal timing in female adolescents might also be associated with an enhanced likelihood of
175 risk-taking behaviours, coupled with an association between late age at menarche and lower

176 education attainment (Calthorpe et al., 2020). Additionally, Roh and Kim (2012) have shown
177 that breast development in girls, which can begin in pre-secondary school (56.5%), is a cause
178 of student worry. Multifaceted findings such as these point to the need for more consideration
179 of more complex, multifactorial influencing factors for academic performance, rather than
180 (biological) age alone (Calthorpe et al., 2020). Therefore, the multifaceted effect of maturation
181 on secondary school students as they navigate adolescence requires further multidisciplinary
182 observational, interventional, and longitudinal examination.

183

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

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

196 When exploring behaviour such as engaging in physical activity or PE, it is important
197 to consider motivational processes, as motivation is said to predict intentional behaviours
198 (Ryan and Deci, 2017). Self-Determination Theory (SDT) (Deci, 2008) differentiates types of
199 motivation on a continuum, from amotivation (which reflects no motivation) to intrinsic
200 motivation, where behaviours are engaged in due to an inherent interest or enjoyment (Ryan

201 and Deci, 2017). In the context of PE, intrinsic motivation is positively associated with
202 increased physical activity levels (Lonsdale et al., 2019) and adaptive outcomes such as
203 intention to engage in physical activity and increased enjoyment (Vasconcellos et al., 2020).
204 Extrinsic motivation, on the other hand, explains how behaviours can be performed for an
205 external consequence (e.g. to avoid punishment, or a financial incentive); this type of
206 motivation is associated with maladaptive outcomes such as boredom and negative affect
207 (Vasconcellos et al., 2020). Nevertheless, Ntoumanis (2002) suggested that only a minority of
208 pupils are intrinsically motivated to participate in PE, and a majority are either externally
209 motivated or amotivated (do not take part). The SDT (Deci, 2008) also explains that there are
210 three basic psychological needs which influence motivation for self-initiated behaviour (e.g.
211 physical activity participation): autonomy (feelings of perceived control), competency (feeling
212 a sense of mastery and an individual's sense that they can meet the demands of challenges) and
213 relatedness (a universal desire to interact with, be connected to, and supported by others). The
214 importance of these needs was supported in a study exploring students' perceptions of the
215 activities they enjoyed and felt competent in (Lewis, 2014). The students who felt they were
216 better at some sports than others typically attributed this opinion to their physical build or
217 aptitude (e.g. bigger children felt better at strength sports).

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

226 (58%) (Dion et al. (2016). O'Donovan and Kirk (2008) explain that PE involves stimuli which
227 could potentially provoke body image disturbance (e.g. changing rooms, PE kit, nature of the
228 activity). Such disturbances are important to understand, as research has shown that body
229 satisfaction is one of the most important contributing factors as to how students perceive PE
230 (Kerner et al., 2018). Given that children of the same age can vary by up to six years in skeletal
231 age (Malina et al., 2015), it might be suggested that grouping PE classes based on chronological
232 age alone could have detrimental effects upon body satisfaction and engagement. Being in a
233 class amongst peers who differ significantly in stature could impact an individual's motivation
234 to participate in sport, their enjoyment during PE lessons, and perhaps ultimately limit future
235 opportunities for engaging in sport and exercise in later life. This is a particularly important
236 consideration when assessing the development of children at either extreme of the maturation
237 continuum (i.e. late or early) (Cumming et al., 2017; Malina et al., 2019; Towlson et al., 2020)
238 where large anthropometric (i.e. stature, body-mass) and physical (i.e. strength, speed, power)
239 within-group differences can manifest (Hannon et al., 2020). These individuals may experience
240 a reduced sense of relatedness and perceived competency (as predicted by SDT), which could
241 increase body consciousness in adolescents due to maturity-related, emphasised differences in
242 body development.

243

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

245 The natural time course of biological maturation is strongly associated with natural
246 anthropometric growth and physical development of adolescent children (Kozieł and Malina,
247 2018; Malina et al., 2004; Towlson et al., 2018), which can have an effect on physical activity
248 engagement and health profiles of developing children (Bacil et al., 2015; Cumming et al.,
249 2014; Cumming et al., 2011). Therefore, it may also be important to consider child maturation
250 status and extra-curricular physical activity when developing the secondary school curriculum

251 and assessing academic development trajectories, given that 51% of 251 examined studies
252 evaluating physical activity and facets relating to academic attainment suggest positive
253 associations between physical activity and academic performance (Rasberry et al., 2011). That
254 said, 48% of the examined studies also showed no such associations (Rasberry et al., 2011),
255 which suggests uncertainty regarding the association between physical activity involvement
256 and academic performance, and which may be a binary phenomenon that warrants attention
257 when developing the secondary school curriculum. In addition to this, maturity-associated
258 consideration has been shown to affect sport participation at recreational (Baxter-Jones et al.,
259 2020; Eisenmann et al., 2020) and development levels (Helsen et al., 2021b; Lovell et al., 2015;
260 Towlson et al., 2017a; Towlson et al., 2018; Towlson et al., 2020) of sport. Specifically, late-
261 maturing children have been shown to be disadvantaged due to (sub)conscious coach bias,
262 where early-maturing boys are more likely to be selected for specialist coaching programmes
263 (Lovell et al., 2015; Towlson et al., 2017b). Such selection bias for male students may well
264 have a negative impact on late-maturing children's continued engagement in PE lessons and
265 opportunity to participate in extracurricular sporting activities. However, such maturity-
266 selection bias seems to be sex-specific, with Baxter-Jones et al. (2020) stating that it does not
267 transcend female sport, with only ice hockey exhibiting a maturity selection bias. Such decision
268 making may be due to a subconscious selection bias of teachers (and coaches) who select earlier
269 maturing peers who possess temporary enhancements in anthropometric characteristics (e.g.
270 advanced stature) which are seen as desirable in some team sports (e.g. soccer, netball, rugby)
271 (Baxter-Jones et al., 2020).

272 In youth sport, coaches' perceptions of young athletes form an integral part of the talent
273 identification process, where evaluations of player performances across games are important
274 for determining a young player's future (Hill et al., 2020a). However, physical advantages
275 associated with early-maturing adolescents can influence coaches' perceptions of talent (Cripps

276 et al., 2016). Indeed, a study exploring coaches' perceptions of long-term potential in male
277 soccer players aged under 16 (female data is unavailable) found that later-maturing players
278 were perceived to have lower long-term potential than average- and early-maturing players
279 (Cripps et al., 2016). Such expectations may in part be explained by either, or an interaction of,
280 biological maturity status and relative age (i.e. the relative age of a person within a group
281 categorised by arbitrary birth month cut-offs). These expectations may also be compounded by
282 psychological phenomena such as Pygmalion effects (psychological phenomenon in which
283 high expectations lead to improved performance), and Galatea effect (raising an individual's
284 self-efficacy which results in an increase in performance) (Hancock et al., 2013). The critical
285 impact of these expectations has also been reflected in early classroom-based studies
286 (Rosenthal and Jacobson, 1968), where teachers' expectancies of students were manipulated
287 by falsely labelling some students as "bloomers" following an intelligence quotient (IQ). Eight
288 to 20 months later the labelled "bloomers" showed a greater increase in their IQ test score
289 compared to the control condition. This phenomenon was explained by teachers changing their
290 behaviour toward students which led to them changing their behaviour in response to these
291 expectations (Rosenthal and Jacobson, 1968). Applying this work to extra-curricular sport, if
292 teachers and coaches are more likely to pay attention to and select earlier-maturing peers due
293 to their enhanced, temporary maturity-related characteristics, later-maturing peers will not only
294 receive less objective opportunity for participating in extra-curricular sport, but their
295 relatedness and perceived competence needs may be thwarted, reducing motivation toward and
296 likelihood of engaging in sport in the future.

297

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

299 It is understood that secondary school aged males engage more in strenuous forms of
300 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

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

345

346 **Biological maturation as a confounding factor for psychosocial development in** 347 **adolescents**

348 Understanding the influence that maturation can have on the development of sex-specific,
349 maturity-related psychosocial behaviours across adolescence (particularly in early- and late-
350 maturing children) is of relevance to teachers, coaches, and guardians. Of course, awareness of

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

370 Functional neuroimaging studies have found that 'social brain' regions in adolescent
371 children may respond to rejection differently (Sebastian et al. (2011). This response is of
372 relevance as such methods may permit future research studies to examine neural bases of
373 responses to social rejection, which is of particular importance for adolescents and young adults
374 given the highly-individualised timing of maturation of regions subserving emotional control
375 and self-evaluative processing during social rejection (Sebastian et al., 2011). Therefore, it is

376 imperative for prospective study designs to investigate the extent to which individual
377 differences during periods of rejection and disappointment may affect adolescents' sense of
378 relatedness and perceived competence, in the context of sport and exercise within and outside
379 of the curriculum. Such issues are particularly relevant for future study design, considering
380 that early- or late-maturing students may compare themselves to their peers due to significant
381 differences in their anthropometric and physical characteristics, their individual experience of
382 rejection (e.g. not being passed to in team sport, not being picked for the team by their coach),
383 or even be subjected to bullying. Research focussed on matters associated with pubertal timing
384 (i.e. early- or late-maturing), which has the potential to produce direct benefits and increased
385 awareness of the underlying mechanisms of maturity timing, is vital for understanding the
386 unique developmental challenges faced by children (Mendle et al., 2007).

387

388 **Summary of the problem**

389 The timing (early or late) of maturation affects physical activity engagement (Bacil et al., 2015;
390 Barth Vedøy et al., 2020; Cumming et al., 2014; Cumming et al., 2012b) and psychological
391 (Andersson and Magnusson, 1990; Burnett et al., 2011; Celio et al., 2006; Fairclough and
392 Ridgers, 2010; Garcia et al., 2018; Sebastian et al., 2011) development of secondary school
393 aged children. All of which collectively can impact a student's academic attainment (Burnett
394 et al., 2011; Dubas et al., 1991; Roh and Kim, 2012), which is also influenced by the effect of
395 maturation on the development of these characteristics across adolescence likely being sex-
396 specific (Bacil et al., 2015; Baker et al., 2007; Cumming et al., 2008; Drenowatz and Greier,
397 2019; Rodrigues et al., 2010), and the magnitude of effect being mediated by whether the
398 individual is late- or early-maturing. For instance, male adolescents engage in more strenuous
399 forms of exercise and total exercise behaviour than females (Cumming et al., 2008; Cumming
400 et al., 2011; Rodrigues et al., 2010), with the timing of maturation (i.e. early- or late-maturing)

401 shown to have a mediating effect on adolescent engagement in physical activity (Bacil et al.,
402 2015; Drenowatz and Greier, 2019; Garcia et al., 2018; van Lenthe et al., 1996) and perceptions
403 of attractiveness (Cumming et al., 2008). However, sport competence is shown to partially
404 mediate relations between maturity status and physical self-worth (Cumming et al., 2008). Such
405 evidence might in part be explained by early-maturing girls possessing morphological
406 characteristics (size, shape, and body composition) that may not be in accordance with social
407 expectations (Garcia et al., 2018), which facilitates the formation of negative self-opinion and
408 emotion. However, it may also be that male students experience contrasting effects of early-
409 maturation. Therefore, it is possible that early-maturing boys, who experience PHV earlier than
410 their peers, will be taller and have enhanced body-mass (Towlson et al., 2018; Towlson et al.,
411 2020). In addition, it is also plausible to suggest that they will perceive such biological
412 developments more positively in comparison to their early-maturing female counterparts as
413 earlier-maturing and older boys have reported more frequent muscle-building conversations
414 and had lower BMIs (Jones and Crawford, 2005). Founded on research-based observations, it
415 is also intuitive to suggest that late-maturing boys and girls will likely experience contrasting
416 effects of maturation in comparison to their early-maturing peers, and the effect of maturation
417 on key areas of child development may impact willingness to engage in PE, lifelong attitudes
418 toward physical activity and individual academic progress.

419

420 **Lessons learnt from within a sport context**

421 Despite evidence to suggest the effect of early- and late-maturation on various facets of child
422 development (Bacil et al., 2015; Barth Vedøy et al., 2020; Cumming et al., 2014; Cumming et
423 al., 2012b; Costa e Silva et al., 2017; Knowles et al., 2009; Niven et al., 2009), there have been
424 few studies within education and child development contexts which have explored
425 interventions which control for maturity status (Kelley et al., 2015). This oversight is surprising

426 given the recommendation by Baxter-Jones et al. (2005) that paediatric researchers must
427 include an assessment of biological age in study designs so that the confounding effects of
428 maturation can be controlled for. Despite a paucity of education-based research, the effect of
429 maturation on physical activity (Cumming et al., 2014; Cumming et al., 2012a; Cumming et
430 al., 2012b; Cumming et al., 2008; Cumming et al., 2009; Cumming et al., 2011) and the over-
431 selection of early-maturing children who are characterised as possessing advanced
432 anthropometric and physical fitness characteristics due to early-PHV exposure for sports
433 coaching programmes has been well-documented (Cumming et al., 2014; Helsen et al., 2021a;
434 Lovell et al., 2015; Malina et al., 2020; Malina et al., 2015; Towlson et al., 2017b; Towlson et
435 al., 2018). This maturity phenomenon results in the chronic under-selection of late-maturing
436 children in team sport who likely possess the potential to develop equal technical and physical
437 abilities as their early-maturing counterparts. Recognizing this problem, sporting organisations
438 have explored the implementation of maturity status bio-banding (Barrett et al., 2022; Bradley
439 et al., 2019; Cumming et al., 2018a; Lüdin et al., 2022; MacMaster et al., 2021; Romann et al.,
440 2020; Towlson et al., 2021a; Towlson et al., 2022; Towlson et al., 2021b).

441 Bio-banding is the categorisation of children according to their biological maturity
442 status, which can be achieved by measures of skeletal age via x-rays or using validated and
443 reliable somatic, estimation equations. Bio-banding has been used across professional soccer
444 organisations to enhance the physical, technical, tactical and psychosocial development of
445 adolescent players (Towlson et al., 2023). The growing popularity of this approach is evidenced
446 by a recent finding that 80% of 31 participating academies have used, or are currently using,
447 bio-banding within their player development programmes (Towlson et al., 2023). This is
448 accompanied by evidence which states that academy practitioners perceive bio-banding to
449 enhance their ability to assess academy soccer players' talent (Towlson et al., 2023). The
450 authors also suggest that practitioners who have used bio-banding believe that the method is

451 an effective way of enhancing the perception of challenge, thereby providing a number of
452 psychosocial benefits (Towlson et al., 2023). Academy soccer-based research has suggested
453 that matching children for maturation has removed the anthropometric and physical fitness
454 differences between them (MacMaster et al., 2021) and that bio-banded children perceive this
455 change in categorisation as more equitable in terms of exertion during physical activity (Barrett
456 et al., 2022), and that it results in a more positive experience (Bradley et al., 2019; Cumming
457 et al., 2018a).

458 In addition to matching children for maturity status, purposefully mis-matching
459 children (e.g. late- vs early-maturers) during bio-banded sessions might also provide late-
460 maturing children with enhanced conditions that will allow them to demonstrate a number of
461 important psychological and behavioural characteristics (Towlson et al., 2021b), which their
462 ‘normal’ chronological age-ordered playing environment does not naturally afford them. For
463 example, when performing in maturity mis-matched bio-banded soccer matches, later-
464 maturing players have demonstrated a number of enhanced and highly desirable psychological
465 characteristics (i.e. positive attitude, confidence, competitiveness) compared to their peers
466 within age-categorised teams (Towlson et al., 2021b). The latter evidence suggests that
467 prescribing a more challenging (but safe) playing environment than what players are typically
468 habituated to may elicit positive performance and developmental benefits. Such potential
469 enhancements in psychological and behavioural characteristics during mis-matched physical
470 activity sessions may be partially explained by the ‘underdog hypothesis’ (Cumming et al.,
471 2018b; Gibbs et al., 2012), which postulates that late-maturing children develop superior
472 psychological skills that enable them to perform equally with their more mature counterparts
473 (Gibbs et al., 2012). More specifically, it could be suggested that late-maturing children possess
474 more advanced self-regulatory skills, which represent the extent to which individuals are
475 metacognitively, motivationally, and behaviourally proactive participants in their learning

476 process (Zimmerman, 2006). For instance, children who are mis-matched in one capacity (e.g.
477 size, speed) must search for alternative strategies (e.g. anticipation, decision making) which
478 allow them to compete. With appropriate levels of challenge and support, mis-matched sessions
479 may be one means by which such desirable characteristics are encouraged and developed. This
480 developmental phenomenon is important for secondary education stakeholders, because
481 enhancing self-regulatory skills has been found to differentiate experts from their less-skilled
482 counterparts (Toering et al., 2012), have lasting improvements on child academic attainment
483 (Schunk et al., 2022), and may provide further insight relating to child PE development
484 trajectories.

485 Bio-banding is also suggested to be an effective pedagogical tool within mixed-aged
486 classrooms, with bio-banding being used to benefit both early- and late-maturing children
487 during the delivery of psychological classroom-based sessions (Hill et al., 2020b). These have
488 been shown to permit enhanced learning and development experiences for children at both ends
489 of the maturity spectrum (Hill et al., 2020b). Although the traditional sporting and education
490 contexts are different (i.e. training ground vs classroom), the demographic populations within
491 these two examples are the same (i.e. secondary school aged). Both contexts comprise children
492 of different maturation status, who are categorised using arbitrary, chronological aged-ordered
493 bandings, resulting in groups of children exhibiting large within-group variations in
494 development (Cumming et al., 2012a; Cumming et al., 2011; Malina et al., 1999). Such
495 variations might create sub-optimal secondary school learning environments, which are
496 confounded by the complex and often negative development consequences for children who
497 are at either extreme (late- and early-maturing) of the maturation continuum. Therefore, is it
498 now time for teachers and researchers to purposefully consider the timings and confounding
499 implications of maturation on academic, psychosocial, and physical development of children
500 (see Figure 1), and explore new, supplementary methods to group children within secondary

501 school PE? If so, teachers and researchers may wish to consider new and innovative methods
502 which negate the potentially detrimental effects of (early/late) maturation status on the student
503 experience and reduce the negative consequences of standing out in a crowd. Unfortunately,
504 however, no study investigating the efficacy of bio-banding within PE currently exists. We
505 conclude this paper with suggestions for next steps to be taken by key stakeholders to permit
506 further consideration, flexibility and engagement in understanding, recognising and removing
507 the considerable effects that maturity status can have on adolescent physical activity and sport
508 involvement. Our literature-informed suggestions for education key stakeholders are five-fold:

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

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

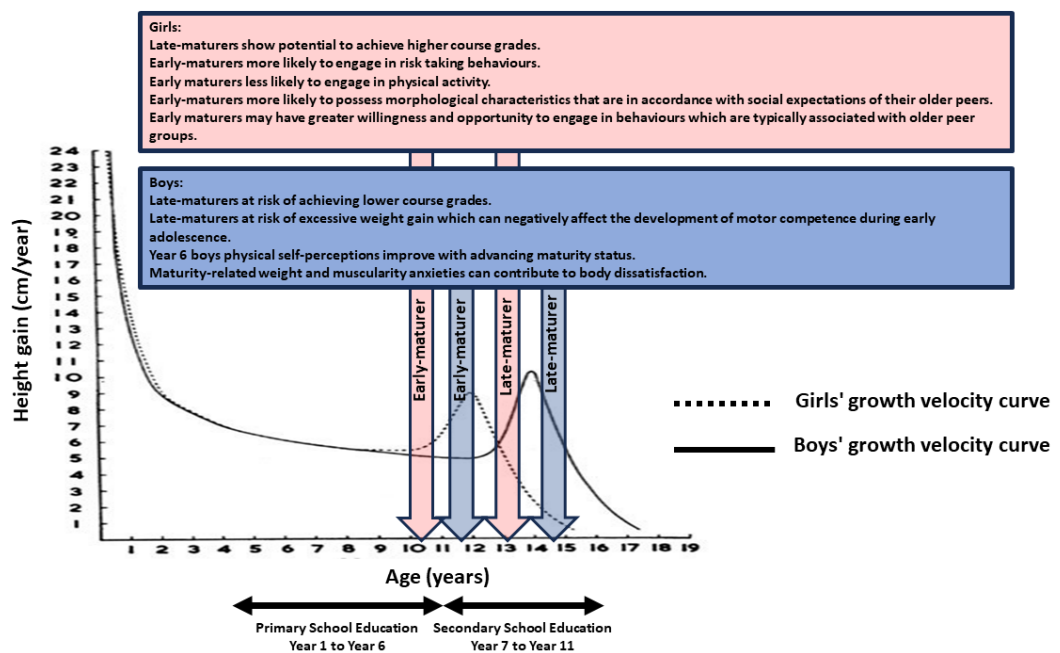
516 3) To ensure that all members of staff are trained and fully understand the
517 methodological considerations when assessing biological maturation (Towlson et al., 2021c).

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

524 5) To understand that bio-banding does not involve categorising children based on their
525 body size or shape. Instead, bio-banding is the categorisation of children according to their
526 biological maturity status, which can be achieved by measures of skeletal age via x-rays or
527 using validated and reliable somatic, estimation equations (appropriate for secondary school
528 environments). The maturity estimation equations (See Mirwald et al. (2002), Moore et al.
529 (2020), Fransen et al. (2018) and Koziel and Malina (2018)) require only measures of stature
530 and body-mass (some equations require parental mid-height) which are used to estimate either
531 the age in which the child will undergo PHV or the percentage of final adult height the child
532 has currently attained (Sullivan et al., 2023) using simple, validated equations (see Towlson et
533 al. (2021c)) . It is this information alone which is used to bio-band children and not body type,
534 shape or size.

535 We recognise the practical challenges (e.g. scheduling disruption) and ethical concerns
536 (e.g. disrupting friendship groups) that key stakeholders may have when considering
537 implementing bio-banding. Teachers will need to explain to children that they are not being
538 categorised on the basis of physical characteristics but rather in an effort to increase inclusion,
539 equity, and the challenges afforded by PE lessons. We recommend that teachers explain to
540 parents, caregivers, and children the rationale for using bio-banding and the various
541 psychological, social and motor benefits that might be derived from this approach.
542 Furthermore, it is important to note that we are not advocating that bio-banding should replace
543 chronological aged-ordered class design nor are we suggesting that bio-banding will inevitably
544 benefit all children within PE settings. We are recommending a more openminded approach
545 whereby stakeholders introduce bio-banding at opportune moments of the academic year
546 (perhaps during science [i.e. biology], personal, social, health and economic education [PSHE]
547 and PE lessons) based on an understanding of their students' physical, technical, motor, and
548 psychological development. Whilst there are challenges with the implementation of bio-

549 banding, we have highlighted a growing body of evidence which suggests that this approach
 550 can have a positive impact on adolescents' enjoyment of sport and their psychosocial
 551 development (Bradley et al., 2019; Cumming et al., 2018a). On the basis of such findings, we
 552 encourage educational researchers to explore the efficacy of bio-banded sessions given the
 553 promise they hold in creating equitable learning environments in which children might flourish.
 554



555

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

559

560 **Declaration of interest-** The authors have no conflicts of interest to declare.

561

Biography-

562 **Dr Christopher Towlson** – Senior Lecturer in Sports Coaching and Performance Science
 563 within the School of Sport, Exercise and Rehabilitation Sciences, University of Hull, UK.

564 **Dr Kate Donnan** – Lecturer in Sport and Exercise Psychology within the School of Sport,
 565 Exercise and Rehabilitation Sciences, University of Hull, UK.

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