



# GROWTH AND MATURATION IN HUMAN BIOLOGY AND SPORTS

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BY FELLOWS AND COLLEAGUES*

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# NEW DIRECTIONS IN THE STUDY OF MATURATION AND PHYSICAL ACTIVITY

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Those interested in the study and promotion of physical activity in children and adolescents have focussed predominantly on the contributions of various psychosocial and environmental factors (Cumming & Riddoch, 2009). Although it is well documented that factors such as self-concept, motivation, and the built environment contribute to physical activity in youth, it is equally apparent that physical activity has a biological basis (Eisenmann & Wickel, 2009; Rowland, 1998; Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). As noted by Malina (2008), physical activity is, after all, a biological process that exists within a cultural context in which various meaning and values are ascribed to it. Thus, a true understanding of physical activity likely resides in the interactions of various biological, psychosocial and environmental factors (Malina, 2008).

A biological process that occurs in all children and youth and may contribute to variance in physical activity is maturation (Eisenmann & Wickel, 2009; Sherar, et al., 2010). Biological maturation denotes progress towards the mature (i.e., adult) state, and can be viewed in terms of tempo and/or timing (Malina, Bouchard, & Bar-Or, 2004). Whereas tempo implies the rate at which maturation progresses, timing refers to the time at which maturity-related events, such as age at menarche, or peak height velocity occurs. Within a chronological age group, children and adolescents can vary considerably in maturity timing, with certain individuals, or groups, maturing much earlier or later than others. For example, girls generally enter puberty two years in advance of boys.

Research examining the contribution of biological maturation to adolescent involvement in physical activity has produced mixed results (Sherar, et al., 2010). Although research has consistently shown that advanced maturation explains why girls are less active and more sedentary when compared against boys of the same chronological age (Cumming, Standage, Gillison, & Malina, 2008; Machado Rodrigues et al., 2010; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007; Thompson, Baxter-Jones, Mirwald, & Bailey, 2003); the effects of maturity timing on individual variation in physical activity within sex are unclear (Sherar, et al., 2010). The physical and functional characteristics associated with advanced maturation in females are considered to be less conducive to successful engagement in most forms of physical activity, particularly activities or sports that involve elements of endurance or weight-bearing (Baxter-Jones, Thompson, & Malina, 2002; Malina, 1994). Accordingly, it has been hypothesized that early maturation in females will be associated with less involvement in most forms of PA (Sherar, et al., 2010). In support of this contention, a number of studies have found early maturing girls to be less active than their 'on time' or late maturing peers (Baker, Birch, Trost, & Davison, 2007; Cumming et al., in

press-a; Cumming, et al., 2008; Cumming et al., 2011; Davison, Werder, Trost, Baker, & Birch, 2007; Hunter Smart et al., in press; Jackson, 2011; Riddoch et al., 2007), and less likely to be represented in competitive sports programmes (Baxter-Jones, et al., 2002; Malina, 1994). It should be noted, however, that an equivalent number of studies have no found no relation between maturity timing and PA in adolescent females (Bradley, McRitchie, Houts, Nader, & O'Brien, 2011; Drenowatz et al., 2010; Knowles, Niven, Fawkner, & Henretty, 2009; Niven, Fawkner, Knowles, & Stephenson, 2007; Romon et al., 2004; Sherar et al., 2009; Wickel & Eisenmann, 2007). That said, only one study, to date, has found early maturing girls to be more active than their peers (van Jaarsveld, Fidler, Simon, & Wardle, 2007).

The nature and direction of the relation between maturity timing and PA in adolescent males is less clear (Sherar, et al., 2010). The physical and functional characteristics associated with early maturation in males are considered to be more conducive to successful engagement in most structured or competitive forms of PA, particularly those that emphasise power, speed, and strength (Malina, 1994). Although early maturing male are more likely to be represented in competitive sports programmes (especially in the older age groups and more elite level programmes) (Malina & Cumming, 2003), there is limited evidence to suggest that early maturing males are actually more or less active than their peers (Sherar, et al., 2010). This suggests that late maturing males, though less likely to be active through competitive sports, remain active in other domains such as recreational play or exercise.

A criticism of research examining relations between biological maturation and physical activity in youth is that it is largely atheoretical, lacking a clear conceptual framework from which to explain and interpret findings (Cumming et al., in press-b; Sherar, et al., 2010). A number of existing conceptual models and hypotheses relating to adolescent and pubertal adjustment, such as Petersen and Taylor's (1980) Model of Biopsychosocial Development, Holmbeck's (2002) Framework for Understanding Adolescent Development and Adjustment, the Peer Socialization Hypothesis (Magnusson, Stattin, & Allen, 1985, 1986), the Puberty-Initiated Mediation Hypothesis (Ge & Natsuaki, 2009; Ge, Natsuaki, Jin, & Biehl, 2011), and the Contextual-Amplification Hypothesis (Ge, et al., 2011; Ge, Brody, Conger, Simons, & Murry, 2002) suggest possible mechanisms that may help explain relations between maturation and PA during adolescence.

Conceptual models of adolescent development and adjustment can be grouped into two main categories, namely *direct* and *mediated* effects (Petersen & Taylor, 1980). Direct effect models contend that maturation exerts a direct causal effect of adolescent psychology and behaviour. Accordingly, adolescent changes in psychology and behaviour, for example reductions in physical activity, are considered to reflect maturity associated changes in biology (i.e., body size, composition, physique, neuroendocrine changes) and attribute individual differences in behaviour to differences in antecedent variables (i.e., biology). Direct effect models would consider adolescent declines in physical activity as an inescapable consequence of the maturation process and 'invariant and universal' feature of adolescent and/or pubertal development (Petersen & Taylor, 1980).

## DIRECT EFFECTS

Support for the existence of *direct effects* is limited. Though some evidence has linked hormones to changes in mood and behaviour (i.e., aggression, sexual behaviour), it is weaker and less consistent than is commonly believed (Buchanan, Eccles, & Becker, 1992; Petersen & Taylor, 1980; Walker, Sabuwalla, & Huot, 2004). This may, however, reflect methodological limitations (e.g., lack of precision and consistency in measurements of hormones and psycho-behavioural outcomes) rather than inadequacies in the theoretical paradigm (Petersen & Taylor, 1980). Despite the lack of evidence supporting the hormonal effects of maturation on psychology and behaviour, the potential for direct effects may be greater in the context of physical activity (Cumming, et al., in press-b). One of the most consistent findings in pediatric exercise science is that individuals become less active as they progress towards the mature state (Eisenmann & Wickel, 2009). The fact that this change is observed across most animal species (Ingram, 2000) also suggests a biological basis for the phenomenon. In support of this contention, research has consistently found that sex-related differences in physical activity and sedentary behaviour among adolescents of the same chronological age are attenuated and non-significant when differences biological maturation are controlled for (i.e., girls typically mature two years in advance of boys) (Cumming, et al., 2008; Machado Rodrigues, et al., 2010; Sherar, et al., 2007; Thompson, et al., 2003).

Further evidence supporting the potential for a direct effect of maturation on physical activity can be found in research examining the purpose of active play (Byers, 1998; Byers & Walker, 1995; Pellegrini & Smith, 1998a, 1998b). Active play is a behaviour that occurs frequently in early and late childhood, yet declines in adolescence through to adulthood. It can also be observed in many animal species, tending to peak around midlactation (Byers, 1998; Byers & Walker, 1995). These observations have led theorists to contend that play is a biologically driven phenomenon that aims to enhance development during time sensitive periods (Byers, 1998). Time sensitive effects that are permanent and specific to play include synaptic pruning, myelination of the neural fibre tracts, and muscle fibre type differentiation (Byers, 1998). Recognizing play as a biological drive, whose purpose is limited to childhood and adolescence, provides a compelling explanation as to why individuals become less active as they progress towards the mature state (Cumming, et al., in press-b). That is, play becomes biologically redundant once certain developmental processes are complete.

## INDIRECT EFFECTS

*Mediated effect*<sup>1</sup> models contend that the psychological and behavioural effects of maturation are mediated and/or moderated by factors endogenous or exogenous to the individual, respectively (Petersen & Taylor, 1980). Mediating factors might include beliefs, self-perceptions, and fantasies and/or attitudes towards the body, physical

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<sup>1</sup> It should be noted that the term 'mediated effects model' is somewhat of a misnomer as such models recognize both mediated and moderate effects

activity, and/or maturation process (Cumming, et al., in press-b). Factors that might moderate relations between maturation and physical activity include peer acceptance, parental support, motivational climate, and cultural values and standards pertaining to the body, maturation, and/or physical activity (Cumming, et al., in press-b). Unlike direct effect models, mediated effect models attribute individual differences in pubertal adaptation to differences in the interpretation and social management of puberty (Petersen & Taylor, 1980). That is, how the individual interprets change during puberty and the meaning and value attached to change is considered to be more important than the change itself. Applying these principles to the context of physical activity, one would predict that youth who are encouraged to view puberty as a normal and positive aspect of the maturation process and not as a barrier to activity would be more likely to remain active through adolescence (Cumming, et al., in press-b).

Potential mediators of relations between maturation and physical activity in adolescents include physical self-concept, body image, self-esteem, acceptance and/or self-presentation anxieties, and attitudes and feelings related to the body, physical activity, and/or the maturation process (Cumming, et al., in press-b; Sherar, et al., 2010). Whereas a number of these potential mediators have been documented as correlates of maturation and physical activity, few studies have actually tested the extent to which these factors actually mediate relations between the variables of interest.

A variable that has received particular interest, as a mediator of relations between maturation and PA, is physical self-concept. Physical self-concept represents the individual's perceptions of the self as generated through his or her experiences with, and interpretations of, the environment related to the physical domain (Shavelson, Hubner, & Stanton, 1976). It has been documented as both a correlate of maturation (Craft, Pfeiffer, & Pivarnik, 2003; Niven, et al., 2007) and as a predictor and outcome of physical activity (Sabiston & Crocker, 2008; Weiss & Amorose, 2005). Advanced maturation in females is generally associated with lower perceptions of physical self-concept (i.e., body attractiveness, sport competence, physical condition, physical self-worth), though early maturing girls do report higher perceptions of strength (Cumming, et al., in press-b). In contrast, advanced maturation in males is typically associated with superior physical self-concept (Lintunen, Rahkila, Silvennoinen, & Osterback, 1988), though evidence is limited.

To date, only a limited number of studies have examined the degree to which physical self-concept actually mediates relations between maturation and physical activity. In a series of three studies testing a mediated effects model, Cumming and colleagues (Cumming, et al., 2011; Hunter Smart, et al., in press) tested the mediating effect of physical self-concept upon relations between maturation and physical activity in adolescent British females. In each study an inverse indirect relation was observed between maturity timing and physical activity. That is, early maturing girls were typically less active than their peers. Similarly, in each study, perceptions of self-competence were found to partially mediate relations between maturation and physical activity. More specifically, girls who were advanced in their maturation generally held lower perception of body attractiveness, sport competence, physical

conditioning, and physical self-worth (yet greater strength), which, in turn, predicted less involvement in physical activity.

As noted previously, the effects of maturation on behaviours such as PA may be moderated by social or cultural factors. The Peer Socialization hypothesis, advanced by Magnusson and colleagues (Magnusson, et al., 1985, 1986), contends that adolescents select peers who are similar in maturity status and, as a consequence, behave in manner that is consistent with their peer groups. Though there is emerging evidence to suggest that early maturing females are less active than their on-time or late maturing peers (Sherar, et al., 2010), it is not clear whether or not this is a result of their associations with older and less active peers. Accordingly, future studies should consider applying the Peer Socialization Hypothesis within the context of physical activity.

Similar to the peer socialization hypothesis, the Puberty-initiated Mediation Hypothesis (Ge & Natsuaki, 2009; Ge, et al., 2011) suggests that the physical and functional characteristics associated with variance in maturity timing hold social stimulus value for significant others (i.e., peers, parents, educators) influencing their perceptions of the adolescent and the nature and quality of their social interactions. Applied to the context of physical activity, the physical and functional characteristics associated with average-to-late maturation in females and average-to-early maturation in males would be considered to be more suitable for successful engagement in most forms of physical activity, especially sports (Malina, 1994). Accordingly, one would expect those individuals to experience a more positive and supportive environment within the context of physical activity (Cumming, et al., in press-b). In support of this contention, Summers-Efler (2004) found that social support from peers and parents, or lack thereof, play an instrumental role in helping adolescent females remain active through puberty. In a similar vein, Cumming and colleagues found that body size in gymnastics was closely related to girls perceptions of coaching behaviours, with girls who were shorter, light, and who carried less mass-for-stature reporting more frequent reinforcement and encouragement, instruction, general communication, and less punishment or ignoring behaviours (Cumming, Eisenmann, Smoll, Smith, & Malina, 2005).

The Contextual Amplification Hypothesis (Ge, et al., 2011; Ge, et al., 2002) has also been proposed to explain the impact of social and cultural factors upon adolescent adjustment. Much like the Peer Socialization and Puberty-initiated Mediation hypotheses, this hypothesis assumes that the sociocultural context in which the adolescent grows up plays an important role in moderating relations between maturity timing and problem behaviours, such as inactivity. Whereas protective or supportive contexts are expected to mitigate any negative consequences associated with variation in maturation (i.e. reduced activity, increased sedentary behaviour), adverse conditions would be expected to amplify these effects. For example, an early maturing adolescent female experiencing an environment that supports activity would be expected to remain as active as her average and late maturing peers. In contrast, an early maturing girl who received limited parental or peer support, grew up in a disadvantaged neighbourhood, or lived in a culture that frowned upon public exercise in females would be less likely to remain active.

To date, only a limited number of studies have explicitly investigated the potential for social and cultural factors to moderate relations between maturation and physical activity. Assuming that a more supportive social environment would mitigate any negative effects associated with advanced maturation on physical activity in females, Pindus and colleagues examined the extent to which peers acceptance moderated relations between maturity timing and physical activity in British adolescent females (Pindus et al., 2011). As expected, advanced maturation was found to be associated with less involvement in physical activity. However, early maturing girls who perceived high levels of peer acceptance were found to be as active as their 'on time' or 'late' maturing peers. In a related study, the moderating effect of parental support for physical activity on relations between maturity timing and physical activity in British adolescent females, aged 11 to 14 years was also studied (Jackson, 2011). Although advanced maturation was associated with less involvement in physical activity, a statistically significant moderating effect for parental support was not observed. Nevertheless, early maturing girls who reported higher levels of parental support reported, on average, higher levels of physical activity than those who reported lower levels of parents support.

Assuming that parental support might mitigate any negative impact of advanced maturation on physical activity in adolescents, Bradley and colleagues examined the relation between maturity timing and parental support on adolescent involvement in moderate-to-vigorous physical activity (MVPA) (Bradley, et al., 2011). Although pubertal timing was found to be unrelated to MVPA in both males and females, parental support moderated the effect of pubertal timing on MVPA in males. Closer inspection of the results suggested that higher levels of high parental monitoring was associated with reduced physical activity in late maturing males, but increased activity levels for early maturing males. The finding of this study should, however, be interpreted with caution as the growth models used to predict change in MVPA included exceptionally large numbers of independent and interactive predictor variables.

## SUMMARY

Emerging evidence suggests that biological maturation and pubertal timing both contribute to variance in physical activity in adolescents. What is also clear is that the relations between biological maturation and physical activity are complex and that a variety of personal and social cultural factors may mediate or moderate relations between these constructs. Professor Malina has undoubtedly played a major role in leading and advancing this line of research, identifying the need to adopt a biocultural approach to the study of maturation and activity and encouraging fellow researchers in their efforts to study this phenomenon. In this respect, I and many of my colleagues will be eternally grateful for his contribution to the field of study, and for his continued advice, support and friendship.

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