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Running head: BIOLOGICAL MATURITY, PHYSICAL ACTIVITY, ADOLESCENCE

**A Biocultural Model of Maturity-Associated Variance in Adolescent Physical
Activity.**

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Abstract

A model for adolescent involvement in physical activity (PA) that incorporates individual differences in biological maturation is presented. The Biocultural Model of Maturity-Associated Variance in Physical Activity recognizes PA as a complex and multifaceted behavior that exists in multiple contexts (e.g., transport, vocation, sport, exercise & others) and can be viewed from multiple perspectives (e.g., energy expenditure, movement counts, performance outcomes & fitness). The model holds that biological maturation can exert both direct and indirect effects on PA during adolescence. Direct effects imply a direct and unmediated effect of individual differences in maturation on PA. Indirect effects imply influences of individual differences in maturation on PA that are mediated by psychological constructs (e.g., self-perceptions, beliefs) and/or are moderated by exogenous factors (e.g., social interaction, culture) associated with pubertal maturation.

Key Words. Growth, maturation, puberty, individual differences, body size

A Biocultural Model of Maturity-Associated Variance in Adolescent Physical Activity

Those involved in the study and promotion of physical activity (PA) have predominantly focused upon the contributions of psychosocial and environmental correlates, such as motivation, knowledge and beliefs, social support, and/or the built environment (Malina, 2008). Although such factors clearly contribute to variance in PA, it is increasingly evident that PA also has a biological basis (Eisenmann & Wickel, 2009; Rowland, 1998; Thorburn & Proietto, 2000). Identical twin and family studies suggest that genetic factors account for an equal, if not greater, proportion of variance in PA and exercise behaviour than environmental factors (Bouchard, Malina, & Perusse, 1997; Buss & Plomin, 1984; van der Aa, De Geus, Van Beijsterveld, Boomsma, & Bartels, 2010). Accordingly, a more complete understanding of PA likely resides in the interactions among biological, psychosocial and environmental factors (Cumming & Riddoch, 2009; Eisenmann & Wickel, 2009; Malina, 2008; Rowland, 1998).

A biological process that occurs in all children and youth and that is pertinent to the study of PA is maturation (Eisenmann & Wickel, 2009). Biological maturation implies progress towards the mature (i.e., adult) state, and can be considered in terms of tempo and/or timing (Malina, Bouchard, & Bar-Or, 2004a). Whereas tempo refers to the rate at which maturation progresses, timing refers to the time at which certain maturity-related events occur (e.g., ages at menarche or peak height velocity). Children and adolescents of the same chronological age vary considerably in maturity timing, with certain individuals or groups maturing much earlier or later than others. Girls, for example, typically enter puberty two years in advance of boys.

The timing of biological maturity (i.e., early, on-time, late) has important implications for physical (e.g., body size and composition, physique, muscular strength) and psychological (e.g., leadership, self-confidence, perceptions of the physical-self) development, and engagement in a range of health-related behaviours, including smoking, drinking, substance abuse, early initiation in sexual intercourse, and PA and sport (Coelho e Silva et al., 2010; Newman & Newman, 2008). Whereas some of these effects are limited to adolescence, others may continue into adulthood (Chen et al., 2011; Clausen, 1975). Early maturing children of both sexes, for example, are generally taller and heavier than their peers from age six onwards (Malina, et al., 2004a). Although differences in height are largely eliminated among individuals of contrasting maturity status in young adulthood, differences in weight and specifically weight-for-height persist. For example, as adults, early maturing females possess greater weight-for-stature and percentage body fat, and a less favourable metabolic phenotype when compared to females who matured 'late' or 'on-time' (Chen, et al., 2011).

The effects of timing of maturity on physical and psychosocial development are most evident in adolescence. Adolescence is a transitional period between childhood and adulthood that involves marked changes in psychology, biology, social roles, and behaviour. Though related, adolescence should not be confused with puberty. Whereas puberty broadly refers to the physical and physiological transformation from childhood to adulthood (although many view it specifically in the context of sexual maturation), adolescence is a broader concept that encompasses physical, emotional, mental, and social change. Adolescence overlaps puberty, yet has no clear criteria denoting initiation and completion. Though adolescence has traditionally been viewed as a single life stage,

research suggests that it can be subdivided into two distinct periods, namely early (12-18 years) and late adolescence (18-24 years) (Newman & Newman, 2008). The chronological age ranges are somewhat arbitrary as many children enter adolescence at 9-11 years, especially girls. These ages are sometimes labelled the transition into adolescence. For the purpose of this paper, the terms adolescence and adolescents will be used in reference to 'early adolescence'.

Maturation and Physical Activity

Biological maturation implies progress towards the mature state and can be assessed in several biological systems, including the skeletal, dental, reproductive and neuroendocrine systems. The degree to which the maturation process influences PA may vary across the various biological systems. For example, sexual maturation (i.e., the development of secondary sex characteristics) may exert a greater effect on daily energy expenditure or sport participation in adolescent females than dental maturation (Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). Primary methods for the assessment of maturation are skeletal, sexual and somatic; dental maturation tends to proceed somewhat independently of the others (Malina et al., 2004a). Though indicators of maturation are generally related, relationships vary with chronological age and indicators. The variation is in part real (reflecting different biological systems) and in part methodological (e.g., discrete versus continuous indicators). The timing and tempo of maturation are largely under the control of genetic factors, although environmental sources of variation need to be recognized (Malina, et al., 2004a). For a more

comprehensive discussion of maturation and its assessment see the review conducted by Malina (Malina, in press).

A commonly accepted definition of PA is the following: ‘...any bodily movement produced by skeletal muscles that results in energy expenditure’ (Caspersen, Powell, & Christenson, 1985). This is largely a public health definition of PA at the most basic level, (i.e., PA as a biological process). PA is, however, a more complex behaviour that varies type or mode, frequency, duration, and both absolute (energy cost) and relative intensity (i.e., proportion of maximal capacity) (Corder & Eklund, 2009). Dependent upon purpose and context, PA can be subdivided into separate domains, including home-time, school, sports, exercise, leisure time, vocational, or habitual PA (Corder, Ekelund, Steele, Wareham, & Brage, 2008; Corder & Eklund, 2009). Methods for assessing PA are both subjective (e.g., questionnaires, interviews, activity diaries (logs), direct observation) and objective (e.g., pedometry, accelerometry, heart rate monitoring, combined sensors).

PA can be considered from multiple perspectives, including health, education, and performance (Malina, 2008). The health perspective typically views PA in terms of energy expenditure and/or the exertion of biomechanical forces associated with potential benefits for the health of the individual and population. Educational and performance perspectives have historically considered PA in terms of physical fitness and/or skill proficiency though, have increasingly recognized the health benefits of PA (Malina, 2008). PA also has a cultural component, with values and meanings attached to various forms of PA differing across cultures and/or societal groups (Malina, 2008). Whereas individuals living in industrialized nations may place greater value on activities such as

sport and exercise, those in developing nations may place greater worth on subsistence activities such as farming, hunting, foraging, or fishing.

There is good reason to believe that biological maturation contributes to adolescent PA (Baxter-Jones, Eisenmann, & Sherar, 2005; Eisenmann & Wickel, 2009; Sherar, et al., 2010). Research has consistently documented that humans, like most animal species (Ingram, 2000), become less active as they progress towards the mature (i.e., adult) state (Eisenmann & Wickel, 2009). Consistent with this observation, sex differences in adolescent PA and sedentary behavior (i.e., boys being more active and less sedentary than girls) are largely attributable to girls maturing two years in advance of boys (Cumming, Standage, Gillison, & Malina, 2008; Machado Rodrigues et al., 2010; Sherar, Esliger, Baxter-Jones, & Tremblay, 2007; Thompson, Baxter-Jones, Mirwald, & Bailey, 2003).

The timing of biological maturation (i.e., whether one is early, on time, or late relative to ones peer group) has also been identified as a potential contributor to variance in adolescent PA. The physical and functional characteristics associated with advanced maturation in males (e.g., greater gains in absolute and relative fat-free mass; larger physical size; superior speed, strength, power) and late maturation in females (e.g., smaller gains in absolute and relative fat mass, more linear physique, better performance in aerobic endurance tests) are more conducive to successful engagement in most forms of PA, in particular competitive sports (Baxter-Jones, Thompson, & Malina, 2002; Malina, 1988, 1996). Advanced maturation in males and, to a lesser extent, average-to-late maturation in females, affords an athletic advantage in tests of functional and motor performance (Lefevre et al., 1988; Little, Day, & Steinke, 1997). The advantages in males

appears, however, to be limited to adolescence; as differences among contrasting maturity groups are largely non-existent and, on occasion, reversed in adulthood (Lefevre, Beunen, Steens, Claessens, & Renson, 1990).

Research in the context of youth sport (the most visible form of PA in youth) has also documented associations between maturity timing and athletic participation/success. Adolescent male athletes tend to be 'on time' or advanced in maturity timing, particularly in sports that emphasize speed, power, and strength (e.g., American football, soccer, rugby). The proportion of early maturing males represented in such programs also increases with age (Malina, Morano, Barron, Miller, & Cumming, 2005) and level of competition (Malina & Cumming, 2004; Malina et al., 2005; Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004b), suggesting an interaction between biological and socio-cultural factors. Adolescent female athletes, in contrast, tend to be late or 'on time', in terms of maturity timing. The prevalence of late maturing female athletes increases in sports that emphasize endurance, weight bearing, or aesthetics (Baxter-Jones, et al., 2002; Malina, 1983; Malina, in press; Malina, Ryan, & Bonci, 1994). Of note, early maturing boys and late maturing girls (i.e., those most likely to participate in competitive sports) would be considered to be in maturational synchrony (i.e. similar stages of the maturation process), making the late maturing boys and early maturing girls maturational outliers. It has been postulated that maturational asynchrony may negatively impact adolescent behavior (Newman & Newman, 2008) and involvement in PA and sport (Malina, 1983).

The contribution of maturity timing to habitual involvement PA is less clear (Sherar, et al., 2010) Although a number of studies have found early maturing girls to be less active than late maturing girls (Cumming, et al., 2008; Cumming et al., 2011;

Davison, Werder, Trost, Baker, & Birch, 2007; Hunter Smart et al., 2012; Jackson, 2011; Riddoch et al., 2007), an equivalent number of studies have documented no differences in PA between girls of contrasting maturity status (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 has found early maturation to be associated with higher levels of PA in adolescent girls (van Jaarsveld, Fidler, Simon, & Wardle, 2007). Evidence relating to maturity timing and habitual PA in males is more limited and inconclusive. Whereas one study has observed early maturing males to be more active than their late maturing peers (van Jaarsveld, et al., 2007), another noted less ambulatory activity in early maturing boys (Romon, et al., 2004). In contrast, four studies suggested no relationship between maturity timing and PA in males, (Bradley, McMurray, Harrell, & Deng, 2000; Bradley, et al., 2011; Riddoch, et al., 2007; Wickel & Eisenmann, 2007). The inconsistent nature of these results likely reflects from a combination of factors, including variation in the age ranges of the participants, the assessment of PA and maturation, and the criteria use to categorize of maturity status.

Conceptual Models of Adolescent Development

Much research examining the effects of biological maturation within the context of adolescent PA has been atheoretical and/or failed to consider factors or processes that may moderate or mediate relations between maturation and PA (Cumming, et al., 2011; Sherar, et al., 2010). Existing conceptual models of pubertal and adolescent

development, such as the Model for Biopsychosocial Development (Petersen & Taylor, 1980) and the Framework for Understanding Adolescent Development and Adjustment (Holmbeck, 2002), suggest possible processes and mechanisms that may explain maturity-associated variation in PA. Such models contend that biological maturation may directly and/or indirectly effect psycho-behavioural development during adolescence, and recognize the contributions of individual differences and contextual factors.

Conceptual models of pubertal and adolescent development have been grouped into two main categories, namely *direct effects* and *mediated effects* (Petersen & Taylor, 1980). *Direct effect* models assume that the biological changes associated with biological maturation and puberty (i.e., body size, composition, physique, neuroendocrine changes) exert a direct unmediated effect on psychological and behavioural development. This implies a direct causal link between biological maturation and psycho-behavioural development / adaptation. Since direct effect models do not recognise mediating or moderating factors, individual differences in psycho-behavioural adaptation are generally discounted or attributed to individual differences in the antecedent variables (i.e., biology). Applied to the context of PA, such models would consider changes in PA as inescapable consequences of the maturation process and ‘invariant and universal’ features of adolescent and/or pubertal development (Petersen & Taylor, 1980).

*Mediated effect*¹ models, such as the Model for Biopsychosocial Development (Petersen & Taylor, 1980) and the Framework for Understanding Adolescent Development and Adjustment (Holmbeck, 2002), assume a more complex relationship

¹ It should be noted that the term ‘mediated effects model’ is somewhat of a misnomer as such models recognize both mediated and moderate effects

between maturation and psycho-behavioural adjustment. These models contend that the effects of maturation on psychological and behavioural adjustment are mediated by intervening variables and/or moderated by external factors. Mediating factors, endogenous to the individual, include beliefs, fantasies and/or attitudes towards the body, PA, and/or maturation. Moderating variables include factors that exist and operate outside the individual. Exogenous factors that may moderate relations between maturation and PA include peer acceptance, parental support, motivational climate, and cultural values and standards pertaining to the body, maturation, and/or PA. In contrast to *direct effect models*, *mediated effect models* attributes individual differences in psycho-behavioural adaptation to differences in the interpretation of the puberty and the social management of adolescence (Petersen & Taylor, 1980).

Direct- and *mediated effect* models present alternative explanations for psycho-behavioural adaptation during adolescence, however, they should not be viewed as mutually exclusive. The capacity for each model to explain maturity-associated variance in PA will likely vary relative to the behaviour of interest and/or the social context in which it is studied. Whereas *direct effect* models may provide a more convincing explanation of maturity-associated changes in fitness or performance, *mediated effect* models may provide a better framework within which to understand individual variation in daily energy expenditure and/or sport participation.

In the absence of a common framework from which to conceptualize relationships between biological maturation and PA (Sherar, et al., 2010), this paper proposes a conceptual model for the study of maturity-associated variance in PA during adolescence (Figure 1). The proposed model includes both *direct* (mediated) and *indirect* (moderated)

effects and various endogenous and exogenous factors that may contribute to maturity-associated variance in PA. The model also recognizes biological maturation and PA as complex and multidimensional constructs that exists in several systems/domains and can be viewed from multiple perspectives. The model is intended as a starting point from which to consolidate and interpret existing literature and to guide future investigations. Using the proposed model as a frame of reference, the paper critically reviews the evidence for *direct* and *indirect* effects of biological maturation on PA in adolescents, and identifies key mechanisms, processes, and/or factors that may *mediate* or *moderate* relationships between the constructs.

A Biocultural Model of Maturity Associated Variation in Physical Activity

Consistent with contemporary theories of adolescent development (Holmbeck, 2002; Petersen & Taylor, 1980), the proposed model (Figure 1) includes antecedent biological factors, psycho-behavioural outcomes, and mediating and moderating factors. The model recognizes the various dimensions of biological maturation and PA and the potential for both *direct* and *indirect* effects. Antecedent biological factors include changes in the neuroendocrine system (e.g., increased levels of growth hormone, gonadotrophic and sex hormones among others), timing and development of secondary sex characteristics including age at menarche, timing of landmarks of the growth spurt in stature (ages at take-off and peak height velocity), maturation of the skeleton (skeletal age) and associated changes in body size, physique and composition. Potential mediators of the relation between maturation and PA include physical self-concept, body image and

satisfaction, self-esteem, attitudes and feelings towards maturation, adulthood and PA.

Moderating factors include social support and acceptance; cultural ideals regarding maturation and PA (including subtle cultural expectations for behaviours at certain ages and overt manifestation of maturation); socialization practices and pressures; competing demands and responsibilities; and opportunities for PA. Dimensions of PA that might be influenced by maturation include absolute and relative energy expenditure, health-related fitness, functional capacities, skill proficiency, sport participation, and performance.

Direct Effects

Support for the existence of *direct effects* comes predominantly from research examining the influence of neuroendocrine factors on outcomes such as aggression, mood, and sexual behaviour. Although there is evidence linking hormones to mood and behaviour, it is weaker and less consistent than is popularly believed (Buchanan, Eccles, & Becker, 1992; Petersen & Taylor, 1980; Walker, Sabuwalla, & Huot, 2004). Limited support may reflect limitations associated with the measurement of endocrine factors (e.g., lack of precision and consistency in measurements of hormones) and/or psycho-behavioural outcomes, rather than inadequacies in the theoretical paradigm.

Perhaps the most compelling evidence of a *direct effect* within the context of PA is the observation that individuals become less active as they progress towards the mature state (i.e., adulthood) It is one of the more consistent findings in PA epidemiology and is especially marked during adolescence (Eisenmann & Wickel, 2009). As previously noted advanced maturation explain why adolescent girls are less active and more sedentary

when compared to boys of the same chronological age (Cumming, et al., 2008; Rodrigues et al., 2010) and why declines in PA and increases in sedentary behaviour occur earlier in girls (Nelson, Neumark-Sztainer, Hannan, Sirard, & Story, 2006). Similar attenuations are observed when the PA data of boys and girls are plotted by years from peak height velocity (PHV) rather than chronological age (Sherar, et al., 2007; Thompson, et al., 2003). However, as PHV occurs two to three years earlier in girls than in boys such studies are invariably comparing girls and boys who are two to three years apart in terms of chronological age.

Maturity-associated reductions in PA in humans and across animal species suggest a biological or genetic basis to PA with a central mechanism potentially residing in the dopamine system (Eisenmann & Wickel, 2009; Sallis, 2000). The dopamine system is believed to play a central role in motivation for locomotion and it has been argued that maturity-related changes in dopamine release and sensitivity may contribute to age-related declines in physical activity (Eisenmann & Wickel, 2009). The extent to which pubertal changes in dopamine release or sensitivity contribute to adolescent declines in PA is, as of yet, unknown. What is clear, however, is that adolescence represents a time period where the brain experiences rapid neural reorganization and there are significant changes in components of the neuroendocrine system.

Support for the potential existence of a direct effect of maturation on PA can also be found in research examining the evolutionary purpose of active play (Byers, 1998; Byers & Walker, 1995; Pellegrini & Smith, 1998). Active play is a behaviour that occurs frequently in early and late childhood, yet declines in adolescence through to adulthood (Pellegrini & Smith, 1998). It can also be observed in many animal species,

tending to peak around midlactation (Byers & Walker, 1995). These observations suggest that play is a biologically driven phenomenon that serves to enhance development during time sensitive periods (i.e. childhood and adolescence). Developmental effects that are particular to active play include synaptic pruning, myelination of the neural fibre tracts, and muscle fibre type differentiation (Byers & Walker, 1995). Recognizing physically active play as a biological drive that is designed to modify development during time sensitive periods, it is easy to understand why youth become less active as the progress towards the mature state. That is, play becomes biologically redundant once certain developmental milestones are achieved.

Further evidence of direct effects, comes from research examining the role of maturation in the development of functional capacity and skill performance. Cross-sectional and longitudinal studies clearly demonstrate that maturity associated changes in size and physique contribute directly to variance in a number of fitness and performance parameters in males, including aerobic capacity, anaerobic power and capacity, strength, agility, and several skills (Malina, et al., 2004a; Naughton, Pearson, & Torode, 2006). Corresponding relations in adolescent females are less marked, but girls who are on time or late in maturity timing, on average, tend to demonstrate superior performances on tests of speed, power and aerobic capacity but inferior performance on tests of static strength (Malina, et al., 2004a). The latter reflects absolute size differences between early and late maturing girls for when expressed per unit body mass, late maturing girls tend to be stronger. The results in both sexes highlight the important role of maturity-associated variance in body size and composition in performance during adolescence (Malina, et al., 2004a; Naughton, et al., 2006).

The potential for PA to exert a direct effect on maturation should also be recognized. PA is, after all, considered a requisite for healthy physical and psychological development (Malina, 2008; Malina, et al., 2004a). Though few studies have examined assessed the long term consequences of PA on maturation, research suggests that children release increasing, yet variable, amounts of growth hormone in response to standardized bouts of moderate-to-vigorous exercise (Seip, Weltman, Goodman, & Rogol, 1990). Conversely, it has been argued that the stress effects associated over-training, the training environment, or competition might inhibit the production rate of GH in youth (Malina & Rogol, in review). The potential direct effects maturation on PA and vice-versa merit further investigation.

Mediating Effects

To date, only a limited number of studies have examined the extent to which various mechanisms mediate relations between biological maturation and PA. A greater number of studies have, however, examined biological maturation or PA in relation to ‘potential’ mediating variables. Potential mediators include physical self-concept, body image, self-esteem, acceptance and/or self-presentation anxieties, and attitudes and feelings related to the body, PA, and/or the maturation process.

Physical Self-Concept. Physical self-concept represents the individual’s perceptions of the self as generated through experience with, and interpretations of, his/her environment related to the physical domain (Shavelson, Hubner, & Stanton,

1976). It has been identified as potential mediator of relations between maturation and PA (Sherar, et al., 2010). Physical self-concept is a determinant and outcome of PA in males and females (Weiss & Chaumeton, 1992); a more positive self-concept predicts greater involvement in moderate-to-vigorous forms of PA, and PA begets a more positive self-concept (Sabiston & Crocker, 2008). In adolescent females, advanced maturation is generally associated with lower perceptions of the physical self-concept (Lintunen, Rahkila, Silvennoinen, & Osterback, 1988) and self-worth (Davison, et al., 2007; Monsma, Malina, & Feltz, 2006; Niven, et al., 2007; Rubin et al., 1993), body attractiveness (Niven, et al., 2007), and sport competence (Craft, Pfeiffer, & Pivarnik, 2003). Conversely, advanced maturation is associated with higher physical self-concept in males (Lintunen, et al., 1988), though research is limited.

Independent associations among physical self-concept, biological maturation and PA are well documented (Sabiston & Crocker, 2008). However, only two studies have examined the extent to which self-concept mediates relations between these maturation and PA. In separate sample of English adolescent girls aged 11-15 years, Hunter-Smart et al. and Cumming et al., tested a series of mediated effects models based on Peterson and Taylor's (1980) Model for Biopsychosocial Development (Cumming, et al., 2011; Hunter Smart, et al., 2012). Structural equation modelling employing bootstrapping procedures provided strong support for the models (Cumming, et al., 2011; CFI = .95; SRMR = .08) (Hunter Smart, et al., 2012; CFI = .95; SRMR = .07) and evidence of mediation effects. In both studies, advanced maturation predicted lower physical self-concept (with the exception of perceived strength) which, in turn, predicted less involvement in PA. Physical self-concept was also found to partially mediate an inverse

relation between maturation and health-related quality of life (Hunter Smart, et al., 2012). Of note, maturation and physical self-worth were most closely associated with perceptions of attractiveness, with early maturing girls reporting lower perceptions of attractiveness and low perceptions of attractiveness predicting lower physical self-worth. Consistent with these observations, qualitative inquiries of adolescent development have noted that physical self-concept and concerns regarding self-presentation play instrumental roles in the decisions of early maturing girls to remain active and engage in various health-related behaviours (Martin, 1996; Summers-Efler, 2004).

Body Image. Body image refers to the individual's perception of the aesthetic qualities of her/his physical appearance, and has also been advanced as a potential mediator of relations between maturation and PA (Sherar, et al., 2010). Body image is based upon an internalized belief regarding the ideal body type, but is be influenced by external factors (e.g., culture). Evidence suggests that body image, like self-concept, serves as a predictor and outcome of PA in adolescent males and females; superior body image predicts greater involvement in PA, and regular PA results in more positive body image (Hausenblas & Fallon, 2006). Adolescent girls with high body image satisfaction are more likely to engage in a variety of health promoting behaviors than their less satisfied peers, including healthy eating and exercise (Kelly, Wall, Eisenberg, Story, & Neumark-Sztainer, 2005). Positive body image is also generally associated with greater PA involvement and maintenance in adolescent males and females (Gillison, Standage, & Skevington, 2011).

Though no studies have, at present, examined the mediating effect of body image on relationships between biological maturation and PA, research suggests that the morphological changes associated with early onset of puberty in girls constitute a risk factor for body image dissatisfaction (Ackard & Peterson, 2001; Levine & Smolak, 2006; Markey, 2010; Monsma, et al., 2006; Siegel, Yancey, Aneshensel, & Schuler, 1999). Paradoxically, normative pubertal changes which coincide with weight gain and increase in adiposity move many girls away from the ideal of a slender female figure prevalent in western culture; thus in many ways, normal puberty leads to a reduction in body image satisfaction among many girls (Abraham, Boyd, Lal, Luscombe, & Taylor, 2009; Levine & Smolak, 2006; Siegel, et al., 1999). Pubertal gains in adiposity are greater in early maturing females so it is not surprising that they more often report inferior body image satisfaction. In contrast to females, early onset of puberty in males is associated with more positive body image (Siegel, et al., 1999). These observations likely reflect pubertal gains in stature and muscular mass (mesomorphy) which are consistent with Western views regarding the ideal male physique.

Attitudes and Feelings Pertaining to Growth, Adulthood, and PA. The internalized thoughts and feelings of adolescents change with physical and physiological maturation which are related to numerous alterations in the hormonal milieu associated sexual maturation and the growth spurt. Attitudes, feelings and perceptions related to growth, maturation, adulthood, and/or the value of PA may mediate relations between biological maturation and PA. How the individual interprets and/or attributes affective meaning to maturational change and/or perceives the importance or appropriateness of

PA may influence the extent to which maturation exerts an effect on PA. Interpretations depend upon a number of factors, including personal belief systems, attitudes and reactions of significant others (e.g., parents, peers, teachers), and societal and cultural values associated with maturation and PA. Adolescents who view pubertal change as a normal and attractive part of the maturation process and PA as an appropriate and valued activity would be expected to remain active, whereas those who perceive puberty in a more negative light or as a barrier to PA would be less likely to remain active. As noted, morphological and functional changes associated with early maturation in males and with on-time or late maturation in females are more consistent with Westernized ideals of athleticism and attractiveness. As such, one might expect early maturing males and average-to-late maturing females to view maturation and puberty in a more positive manner and not as barrier to continued involvement in PA.

Research pertaining to the roles of thoughts and feelings in relation to maturation and PA is largely restricted to qualitative inquiries of adolescent development in females. Though limited, such studies (Summers-Efler, 2004) provide compelling evidence that the thoughts and feelings of girls about their bodies and sexuality, and strategies they employ to cope with pubertal development influence their involvement in PA. Early breast development in girls, for example, was often viewed as a barrier to PA, irrespective of athletic ability (Summers-Efler, 2004). Girls who viewed their development with a sense of embarrassment were more likely to cease participating in activities; *'I wouldn't get in a leotard because I had breasts. I quit gymnastics and that was awful because I was really good at gymnastics. I was embarrassed; like I wouldn't wear anything, I was always wearing big clothes. I hated the whole thing; it made me*

miserable.' (p.37) (Summers-Efler, 2004, p.37). In contrast, girls who were not embarrassed by their physical development and/or who refused to accept that the early onset of puberty served as a barrier to activity, despite its potential athletic disadvantages, were more likely to remain active through adolescence; *"I was like, yes, I have breasts, but they're not going to stop me from doing things I like. I was very much a tomboy and then this happened [breast development], and it was really hard to stay athletic. When you're a girl, and they notice they're like, "why don't you just watch us play." I would say, "no!" I think because I was very stubborn, and I refused to accept that I was going to be left out of stuff because of something that I couldn't control, people began to see that I was still the same old person"* (p.38) (Summers-Efler, 2004, p.38). Reactions and support of significant others, particularly parents, played an important role in helping girls interpret pubertal change in a positive manner (Summers-Efler, 2004). In a related study, no differences were observed in perceptions of barriers to PA were noted among early and late maturing Canadian girls (Sherar, et al., 2009). The girls, however, ranged in age from 8 to 16 years and it is possible that maturity-associated perceptions of barriers to PA may only emerge during adolescence.

Additional Potential Mediators. It is likely that other variables related to the personality also mediate relations between these maturation and PA. Potential mediators include self-esteem, self-efficacy, social physique anxiety, and autonomy. The concept of autonomy would appear particularly relevant to PA in adolescents and refers to the individual's ability to feel, think, make decisions, and act on their own accord (Steinberg, 1999). The development of autonomy is a developmental challenge that all adolescent

face, yet, like puberty, occurs at different times for different individuals (Russell & Bakken, 2002). Similarly different aspects of autonomy may develop at different times within individuals. Although the development of autonomy helps prepare children for adult hood, attempts to assert autonomy can result in negative health choices or social conflict. Understanding how variance in biological maturation may contribute to autonomy development and its relation to health behaviours could be an important step in better understanding relations between maturation and PA during adolescence.

Moderating Effects

The period of adolescence is characterised by heightened social interest, sensitivity, and awareness (Holmbeck, 2002; Newman & Newman, 2008; Petersen & Taylor, 1980).

Thus, the sociocultural environment plays an increasingly important role in shaping attitudes, self-evaluations, beliefs (e.g., who I am, how I should behave, & what can I expect), and behaviours of adolescents (Hargreaves & Tiggemann, 2003b). Adolescents, however, are less capable of critically evaluating or interpreting such messages, and/or differentiating between realistic and unrealistic goals compared to adults. As a result, they may be particularly susceptible to negative social or cultural influences during this phase of development (Hargreaves & Tiggemann, 2003a; Newman & Newman, 2008).

Physical and functional changes associated with variance in maturity timing hold significant social stimulus value for peers, parents, and educators, and can influence the nature and quality of social experiences and interactions for adolescents. Early maturing males, for example, are perceived as being more confident, conventional, relaxed,

attractive (Jones & Bayley, 1950), popular (Jones, 1965), effective in leadership, and less dependent (Mussen & Jones, 1957). The social implications of advanced maturity in females are less clear. Whereas some studies have observed early maturing girls to be more popular and carry greater social prestige (Faust, 1960), others have found late maturing girls to be perceived as more confident, outgoing and assured (Jones, 1965), and less likely to experience high levels of conflict with parents (Wierson, Long, & Forehand, 1993).

The perceptions, reactions, and impressions imparted by others and the images, messages, and scenarios conveyed through the media and other cultural contexts may moderate relations between maturation and PA (Cumming, Eisenmann, Smoll, Smith, & Malina, 2005; Sherar, et al., 2010). As noted, early maturing males and average-to-late maturing females are characterized by physiques that are considered more athletic and more consistent with western ideals pertaining to the ideal body type. Thus, one would expect these individuals to perceive and/or experience a sociocultural environment that was more supportive and conducive to sustained involvement in PA (i.e., greater social support and encouragement, greater consistency with cultural ideals regarding athleticism and attractiveness). Conversely, a more positive or supporting social environment might mitigate potentially negative effects on PA and/or health associated with maturational timing. Mrug and colleagues, for example, observed that early maturing girls who experienced positive parenting were less susceptible to engagement in delinquent behaviours (Mrug et al., 2008).

Research examining the influence of societal and cultural factors on relationships between biological maturation and PA is limited. Relationships (main and interactive)

between pubertal timing and parental support on age-related changes in the moderate-to-vigorous PA (MVPA) were examined in 801 participants in the NICHD Study of Early Child Care and Youth Development (Bradley, et al., 2011). Although pubertal timing was not related to MVPA in both sexes, parental support moderated the effect of pubertal timing on MVPA in males, but not females. More specifically, high parental monitoring was associated with decreased activity levels for late maturing but with increased activity levels for early maturing males. The finding should be interpreted with caution as the growth models used to predict change in MVPA included exceptionally large numbers of independent and interactive predictor variables ($n=38$), likely resulting in high levels of multicollinearity.

The moderating effect of perceived peer acceptance on relations between maturity timing and PA in British adolescent females, aged 11 to 14 years has also been considered (Pindus et al., 2011). Although girls who were in advanced in maturation were less active than those who were on-time or late (as expected), high perceptions of peer acceptance mitigated the negative effect of maturation on PA. That is, early maturing girls with high perceptions of perceived acceptance were as active as girls who were on-time or late maturing. In a related study, the moderating effect of parental support for PA on relations between maturity timing and PA in British adolescent females, aged 11 to 14 years was also examined (Jackson, 2011). Although advanced maturation was associated with less involvement in PA, 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 PA than those who reported lower levels of parents support.

Summers-Efler's retrospective qualitative study of girls who experienced early breast development provides additional evidence that parents and peers are instrumental in determining continued involvement in PA in adolescent girls (Summers-Efler, 2004). Early maturing girls who curtailed their PA often did so to hide their bodies from public view or because others overtly discouraged them from being active. Male peers appeared particularly uncomfortable engaging in active pursuits with early maturing girls, encouraging them to watch rather than play. Conversely, early maturing girls who remained active through puberty reported higher levels of support and acceptance from parents, peers, and coaches. Social support and acceptance may thus play a particularly important role in the experiences of early maturing girls, helping in the prevention of internalization and in the development of defensive or maladaptive coping strategies (Summers-Efler, 2004).

It has been contended that positive experiences in sport can serve as potential source of power and status for early maturing girls, undermining other sexually objectifying interactions (Summers-Efler, 2004). Sports that place less emphasis on the visual display of the body, do not require the wearing of revealing attire, and/or minimize the opportunity for sexual objectification (e.g., soccer) are considered most conducive to positive experience in PA for early maturing girl as they afford greater opportunity for integration of the body within the individual's greater identity (Summers-Efler, 2004). Sports/activities that provide more opportunity for social interaction/support (i.e., team sports) or emphasise technical proficiency and tactical knowledge over physical aptitude might also be more conducive to the involvement of early maturing girls.

Physical and functional characteristics associated with variance in maturity timing may also influence the socialization experiences in sport among adolescents. Benjamin Bloom, a pioneer in the study of talented individual in several domains, commented that children who possess the most suitable physical characteristics for success in a given sport are treated preferentially through formal and informal means. That is coaches and educators react differently to youth of varying size and/or physiques. Differential treatment might include early identification, greater investment in terms of time and resources, more opportunity to compete to play important roles, and greater social recognition and rewards (Bloom, 1985). It should be noted, however, that Bloom's focussed predominantly on sports (tennis & swimming) and activities in which individual's attained success at a relatively early age.

The formal and informal use of growth and maturity characteristics to include/exclude athletes and predict athletic potential has been documented in a number of sports, and is more common in aesthetic sport and/or programmes that aim to produce professional or world class athletes (Hartley, 1987). For example, the former Russian and former-East German elite development gymnastics programmes operated a formal selection policy where potential athletes were initially screened, between the age of 3 to 7 years, on the basis of morphological and maturational characteristics and physical health (Hartley, 1987). Less formal socialization and/or selection strategies include preferential treatment or support. For example, Cumming and colleagues observed that perceptions of positive and negative coaching behaviours were associated with body size of adolescent female gymnasts (Cumming, et al., 2005). Gymnasts who were shorter, lighter, and carried less mass-for-stature perceived their coaches as more supportive and instructive,

and less punitive or likely to ignore mistakes. In a similar vein, endomorphy (i.e., possessing a rounded and stocky physique with a tendency to obesity) was inversely related to performance scores (i.e., subjective evaluations of judges) at the 1987 World Championship of Artistic Gymnastics suggesting a judging preference towards gymnasts with more linear physiques (Claessens, Lefevre, Beunen, & Malina, 1999). Consistent with these observations, girls who dropped out of artistic gymnastics were chronologically older, taller and heavier, and advanced in skeletal maturation (Claessens & Lefevre, 1998).

Further evidence of adults responding to the physical and maturational characteristics of young athletes can be found in accounts of the early sport experiences of elite athletes. In a series of interviews with over 100 elite level female gymnasts and figures skaters, it was noted that athletes in these aesthetic sports often experienced “enormous pressure” and expectations to remain thin for the purpose of athletic success and to “conform to and promote the image of the sport” (Ryan, 1995). The account also indicates “belittling insults” from coaches on the bodies of athletes and the risks that such behaviours pose in relation to the development of eating disorders. Instances of coaches encouraging athletes to restrict their eating in order to delay maturation are also indicated (Ryan, 1995, p.8). What is not clear, however, is the role of parents of elite athletes in these sports. Are they so focused on success of their daughters that they are complicit in the process? Nevertheless, pressures to stay thin when the normal course of growth and maturation is to gain weight and height and to mature can have serious ramifications for both physical and psychological development. Conversely, Burns (1996) discusses how coaches affiliated with professional soccer clubs have, on occasion, recruited physicians

to accelerate the growth and maturity of talented yet physical small players. The administration of chemical substances such as synthetic growth hormone or anabolic steroids may be warranted in cases where an athlete suffers from growth failure, as in the case of Lionel Messi. Such treatments should be administered by a paediatric endocrinologist and should not be performed for the purpose of enhancing athletic aptitude or performance (Cumming, Standage, & Malina, 2004).

Summary

The purpose of this review was to propose a conceptual model for the study of maturity-associated variance in PA during adolescence and to critically evaluate the evidence for *direct* and *indirect* effects of biological maturation on PA. The review reveals an emerging body of evidence to support potential for both *direct* and *indirect* effects of maturation of various dimensions of PA. However, it also highlights limitations in the understanding of the relations between these constructs and the need to address methodological and analytical limitations in the extant literature. Presently available research provides equivocal findings, but is limited by relatively small sample sizes, lack of consideration for mediating and/or moderating factors, and quality assessments of maturity and PA (Sherar, et al., 2010). Nevertheless, the proposed model serves as a suitable starting point from which to consolidate the available observations and to consider the various factors and mechanisms that may explain relationships between biological maturation and PA.

Recommendations for the further study of maturation and PA in adolescents have been suggested (Malina, 2008; Sherar, et al., 2010) and include the need (1) for a biocultural perspective; (2) to differentiate between effects of actual and perceived maturity timing; (3) to selectively sample youth at the extremes of the maturity continuum; (4) to control for social desirability; and (5) to consider individual differences in sensitivity and responsiveness to changes associated with normal biological maturation. While the recommendations are well founded and seemingly obvious, the current review also highlights the importance of adopting developmentally-oriented research strategies that focus on variables that are developmentally relevant to adolescents, such as changes in personal autonomy, self-concept, and interactions with parents and peers (Holmbeck, 2002). Rather than simply documenting whether these variables increase or decrease over time, it is important to track changes in these variables as a function of changes in important developmental processes. For example, adolescent reductions in PA may reflect important developmental changes in morphological and functional characteristics, belief systems, self-perceptions, and/or the social relationships.

Researchers should also consider the use of a mixed-methods approach (i.e., combination of quantitative and qualitative methods) to study different “trajectory groups,” (e.g., those that remain active through adolescence versus those who do not), for the purpose of understanding how the groups differ as a function of developmental changes in relevant biological, individual, social, and environmental factors (Holmbeck, 2002, p.413). A mixed methods approach (Brannen, 2004, 2005) would appear particularly useful in terms of addressing the complex and multifaceted nature of the subject matter and explaining individual differences in adolescent adjustment. Researchers would also

do well to compare and contrast the developmental trajectories of early maturing girls who are active versus inactive through adolescence. Knowledge of developmental differences in PA would inform subsequent interventions, helping practitioners more accurately identify those in need of support and more effectively tailor the treatment to the individual.

In conclusion, there is growing evidence to suggest that biological maturation contributes to variance in PA in adolescents, and that this relation is evident across various dimension of both maturation and PA. Understanding of relations between these constructs is, however, limited and much remains to be done. Those involved in the sports and exercise sciences would do well to adopt a biocultural and/developmental approach and consider methodological and analytical strategies employed in other developmentally oriented disciplines. Such approaches will lead to a better understanding of how biological maturation does or does not influence PA in adolescents.

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Figure 1. A Biocultural Model of Maturity Associated Variation in Adolescent Physical Activity

