Maturational timing, physical self-perceptions and physical activity in UK adolescent females: Investigation of a mediated effects model

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Cumming, S.P, Harrington DM, Davies MJ, Edwardson CL, Gorely T, Khunti K, Rowlands, AV, Yates T, Sherar LB

Sean Cumming, Department for Health, University of Bath, Bath, BA2 7AY

Deirdre M. Harrington, Alex Rowlands, Melanie J. Davies, Kamlesh Khunti, Thomas Yates & Charlotte L. Edwardson. University of Leicester, Diabetes Research Centre, Leicester General Hospital, Leicester, LE5 4PW, UK

Melanie J. Davies, Alex Rowlands, Thomas Yates & Charlotte L. Edwardson NIHR Leicester Biomedical Research Centre, Leicester, Leicester General Hospital, Leicester, LE5 4PW, UK

Kamlesh Khunti, Applied Health Research and Care East Midlands, Leicester General Hospital, Leicester, LE5 4PW, UK

Trish Gorely, Centre for Health Science, University of the Highlands and Islands, Inverness, IV2 3JH, UK

Lauren B. Sherar, School of Sport, Exercise and Health Sciences, Loughborough University, Loughborough, LE11 3TU, UK

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Abstract

Background: Advanced (early) biological maturation may be a risk factor for inactivity among adolescent girls. The aim of the present paper was to test the mediational effects of body attractiveness and physical self-worth on the relationship between biological maturity and accelerometer assessed moderate-to-vigorous physical activity (MVPA) in a large multi-ethnic sample of girls from the Midlands area in the UK (11-14 years).

Methods: Biological maturity (predicting age at peak height velocity (APHV)); self-perceptions of body attractiveness, physical self-worth, and minutes spent in MVPA were assessed in 1062 females aged 11 to 14 years.

Results: Structural equation modeling using maximum likelihood estimation and boot-strapping procedures supported the hypothesized model. Later maturation predicted higher perceptions of body attractiveness (β=.25, $p<.001$) which, in turn, predicted higher perceptions of physical self-worth (β=.91, $p<.001$) and, significantly higher MVPA (β=.22, $p<.001$). Examination of the bootstrap-generated bias-corrected confidence intervals suggested that perceptions of body attractiveness and physical self-worth partially mediated a positive association between predicted APHV and MVPA (β=.05, $p<.001$).

Conclusions: Greater biological maturity (i.e. early maturity) in adolescent girls is associated with less involvement in MVPA and appears to be partly explained by lower perceptions of body attractiveness and physical self-worth. Physical activity interventions should consider girls perceptions of their pubertal related physiological changes during adolescence, particularly among early maturing girls.

Maturational Timing, Physical Self-Perceptions and Physical Activity in UK Adolescent Females: Investigation of a Mediated Effects Model

Introduction

Maintaining at least the recommended level of moderate-to-vigorous physical activity (MVPA) is a well-accepted lifestyle target for promoting physical and mental health in adults as well as children and young people (Ekelund et al. 2012). Evidence suggests, however, that a significant proportion of adolescents (77·6% of boys and 84·7% of girls) globally do not achieve this minimum recommended level (Guthold et al. 2019 Nov).

Adolescence is recognized as a period of great physical, psychosocial, cognitive, and emotional change. Variance in the age that an individual enters into puberty may contribute towards physical (in)activity during adolescence, especially among girls (Malina, Robert M. Bouchard, Claude. Bar-Or 2004). Biological maturation refers to the progress towards the mature state and can be defined in terms of status (specific stage of maturation), tempo (rate at which maturation occurs) and timing (age at which specific milestones, such as age at menarche or age at peak height velocity (APHV) occurs). Children of the same chronological age can differ significantly in their degree of biological maturation with some individuals maturing earlier or later than their peers (Malina, Robert M. Bouchard, Claude. Bar-Or 2004).

Maturation has been proposed as one reason why girls tend to be less active (Sherar et al. 2007) and more sedentary (Machado Rodrigues et al. 2010) than boys of the same chronological age. Consistent with this finding, girls who are advanced in maturation for their age (i.e. early maturers) have also been shown to be less active

(Cumming, Gillison, et al. 2011) and more sedentary (Machado Rodrigues et al. 2010) than later maturing girls of the same age (i.e. late maturers). This effect may be greater when considered at the extreme ends of the maturity continuum (i.e., most versus least mature girls) (Cumming, Sherar, Smart, et al. 2012). Evidence supporting the association between maturation and physical activity is, however equivocal, potentially reflecting variation in the definitions and measures of both biological maturity and physical activity, small sample sizes, and a general failure to consider potential mediating and/or moderating factors (Sherar et al. 2010).

The relationship between maturation and physical activity in girls is complex and multifaceted. The Biocultural Model of Maturity Associated Variance in Physical Activity (Cumming, Sherar, Pindus, et al. 2012) posits that biological maturation may directly and/or indirectly impact activity in youth. Specifically, it argues that the impact of maturation on physical activity may be mediated and/or moderated by endogenous (e.g., beliefs, ideas, self-perceptions) or exogenous (e.g., societal and cultural expectations and values, environment) factors, respectively. That is, perceptions of physical changes during puberty and the reactions and evaluations of others may be as, if not more, important than the changes themselves. In support of these contentions, perceptions of the physical-self, in particular attractiveness and sports competence has been shown to mediate inverse relations between biological maturation and self-reported physical activity in a sample (n=244) of 11-14 year old British adolescent females (Jackson et al. 2013). Higher levels of peer acceptance have also been observed to mitigate the negative impact of early maturation upon self-reported physical activity in another sample (n=342; 7-9 year old) of adolescent British girls (Pindus et al. 2014). The

results of these studies should, however, be interpreted with caution as the majority have involved fairly small samples and self-reported measures of physical activity, which are subject to biases associated with social desirability and recall (Shephard 2003).

The aim of the present paper was to test the mediational effects of body attractiveness and physical self-worth on the relationship between biological maturity and accelerometer assessed MVPA in a large multi-ethnic sample of girls from the Midlands area in the UK (11-14 years).

Method

Participants

Cross sectional data for analyses were obtained from the baseline assessment of a cluster randomized controlled trial (RCT) that aimed to evaluate the effectiveness of a school-based physical activity intervention for girls. The protocol (Edwardson et al. 2015) and results (Harrington et al. 2018) of the trial have been published previously. In brief, the RCT included 20 secondary (high) schools in the Midlands area of the UK. Approximately 90 girls, 11–14 year old, were invited at random to participate from each school. After receiving Head Teacher consent, parents were asked to provide opt-out consent (i.e., contact the school/researchers if they did not wish their child to take part) and verbal assent was obtained from pupils. Ethical approval was obtained from the University of Leicester College of Medicine and Biological Sciences (4667-mlh31-diabetesresearchcentre).

Measures

Participants completed a series of self-report questionnaires, including demographic information and subscales from the Physical Self-Perception Profile (Whitehead 1995). Standing height, weight and seated height were measured using standardized procedures. Chronological age in decimals was determined by the difference between date of birth and date of measurement.

Accelerometry

Participants were asked to wear the GENEActiv Original accelerometer (Activinsights Ltd, Kimbolton, UK) continuously (i.e., 24 h/day) for seven days on their non-dominant wrist. This device is a valid and reliable objective measure of physical activity in young people (Schaefer et al. 2014). An in-depth description of the accelerometer processing can be found here (Hansen et al. 2018 Apr 6). In brief, the devices were initialized to collect data at 100 Hz and the data downloaded using GENEActiv PC software version 2.9. The GENEActiv.bin files were processed and acceleration averaged over 5second epochs using R-package GGIR version 1.2–2 (http://cran.r-project.org) (Migueles, J.H., Rowlands, A.V., Huber, F., Sabia, S., van Hees 2019). Detection of non-wear followed the protocol published by Van Hees (van Hees et al. 2013) and was estimated on the basis of the SD and value range of each axis, calculated for 60-min windows with a 15-min sliding window. The window is classified as non-wear if, for at least two of the three axes, the standard deviation (SD) is less than 13 mg or the value range is less than 50 mg. Monitored days were classified as invalid and excluded if wear time was less than 16 h (Edwardson et al. 2015). Physical activity was expressed as total time accumulated in MVPA, defined as time accumulated above an acceleration of 200 mg (Hildebrand et al. 2014)

Predicting Biological Maturity

Stature (i.e., standing height), sitting height, leg length (stature minus sitting height), age, and their interactions were used to predict how many years a girl is from APHV (Mirwald et al. 2002), an indicator of biological maturity. This method assumes that a girl who experiences APHV at an earlier age is more advanced in their biological maturity than a girl who achieves it at a later age.

Perceptions of the Physical Self

Two adapted subscales from the physical self-perception profile (PSPP; Whitehead 1995) were used to assess perceived physical self-worth and body attractiveness. These subscales were completed by participants in the Girls Active Study as part of a larger battery of self-report questionnaires. To limit the number of items participants were required to complete, the other subscales from the PSPP were not included. Both subscales required participants to indicate their agreement with a series of 6 items on a five-point Likert scale, with responses ranging from 'strongly disagree' to 'strongly agree'. Theoretically, physical self-worth is a higher-order construct, with body attractiveness acting as lower-order construct, contributing to physical self-worth. Both subscales demonstrated good levels of internal consistency in the current sample (Physical self-worth: Cronbach's alpha =.85; Body attractiveness Cronbach's alpha =.83).

Statistical Analyses

Descriptive statistics were calculated for anthropometric variables, predicted APHV, body attractiveness, physical self-worth, accelerometer wear time (days), and MVPA. Pearson product moment correlations (one-tailed) were then calculated to investigate relations among the primary variables of interest. Finally, structural equation modeling (SEM), utilizing maximum likelihood estimation and bootstrapping procedures, was used to assess the model fit. To assess the adequacy of model fit, a 2-index presentation strategy advanced by Hu and Bentler (Hu and Bentler 1999) was employed. This strategy uses the Standardized Root Mean Square Residual (SRMR) and incremental or absolute indexes of fit (e.g., Comparative Fit Index -CFI). An SRMR value at or below .08 is indicative of a well-specified model whereas CFI values of .90 and .95 represented acceptable and excellent model fit, respectively (Hu and Bentler 1999). In line with recommended practice (McKinnon et al. 2016), the mediated effects were explored by examining the 90% upper and lower limits of bootstrap-generated bias-corrected confidence intervals (BBC CI) of indirect effects.

Results

Descriptive Statistics

Of the baseline sample, 691 (39%) were excluded because there were missing data on physical self-worth/body attractiveness, accelerometry and/or predicted APHV. Therefore, the final sample retained for the analysis was 1062 (Mean age = 12.8 years, SD = 0.8 years; range = 11-14 years). There were no significant differences between those excluded and those included in the analyses in any of the descriptive variables. Approximately 79% of the sample described themselves as white, 9% as Asian, 4% as Black, 5% as mixed race, and 3% as other. Descriptive statistics for chronological age,

ethnicity, body size, and predicted APHV, body attractiveness, physical self-worth, and physical activity are summarized by chronological age group in Table 1. In all age groups, the mean value for APHV was slightly greater than the expected mean of 12.1 years in European females. (Malina, Robert M. Bouchard, Claude. Bar-Or 2004) Compared to UK-WHO reference values (Freeman et al. 1995), mean heights fell between the 50th and 75th centiles for age at 12 and 13 years of age, and approximated the 50th centile at 11 and 14 years of age. Mean values for weight were between the 50th and 75th centiles at age 11 and 12 and approximated the 75th centile at 13 years and 14 years. Mean values for BMI lay between the 50th and 75th centiles from 11 to 13 years of age and approximated the 75th centile at 14 years of age.

[Table 1 near here]

Correlations

Pearson product moment correlations between measures of maturation, body size, body attractiveness, physical self-worth, and physical activity are presented in Table 2. As expected, predicted APHV was positively associated with higher perceptions of attractiveness, physical self-worth, and minutes engaged in MVPA. Similarly, minutes spent in MVPA was positively associated with higher perceptions of attractiveness and physical self-worth.

[Table 2 near here]

The Mediated Effects Model

Structural equation modelling using maximum likelihood estimation was used to test the fit of the hypothesized model (see Figure 1). Inspection of the Mardia's Coefficient value (41.20, $p < .001$) indicated that the data departed from multivariate normality. Accordingly, the SEM analysis was performed using the bootstrapping procedure with 5000 bootstrap replication samples to provide more accurate assessments of the parameter estimates' stability (Bryne 2001).

[Figure 1 near here]

The model fit indices demonstrated a good level of fit between the proposed model and the data (SRMR = .06; CFI =.89). Modification indices (>10.0) and standardized residuals of the covariance matrix (CR > 2.58) were examined to identify potential areas of model misspecification. Only changes that were theoretically and empirically substantive and resulted in statistically significant improvement in model fit were considered. The standardised residuals did not identify any areas of model misspecification. The modification indices did, however, suggest that model fit could be improved by correlating a number of the error variances associated with psychometric items that shared a common subscale (CFI = .93; SRMR =.05). As these modifications did not result in any substantive changes to magnitude and direction of the path coefficients, and for easier comparison and evaluation of the model in future studies, we are presenting the results for the original non-modified model. Versions of the model controlling for ethnicity and deprivation were also conducted, however, as these variables

did not impact model fit and/or direction or statistical significance of any of the direct and indirect parameter estimates they were not included in this paper.

The standardized Beta coefficients, standard errors, and squared multiple correlations associated with the original hypothesized model are presented in Figure 2. APHV was positively associated with perceived body attractiveness (β=.25, p<.001). Perceived body attractiveness positively predicted physical self-worth (β=.91, p<.001) which, in turn, positively predicted greater MVPA (β=.22, p<.001). Predicted APHV was found to positively and indirectly predict both physical self-worth (β = .23 (90% CI ± .05), p<.001) and MVPA (β = .05 (90% CI ± .02, p<.001), p<.001). An indirect and positive association between perceived body attractiveness and MVPA was also observed (β = .20 (90% CI ± .05), p<.001).

Baron and Kenny's protocol for testing meditational hypotheses (Baron and Kenny 1986), adapted for SEM (Shrout and Bolger 2002), was used to test for mediation of the indirect effect between APHV and MVPA. Bootstrap-generated bias-corrected confidence intervals were employed to estimate the standardized path coefficients representing the direct effect, with and without the mediating variables. Without the mediating variables the direct path coefficient between APHV and MVPA was statistically significant (β = .11 (BBC 90% CI = .06, .16), p<.001). When the mediating variables were included within the model the path coefficient representing the direct effect between APHV and MVPA was attenuated but remained statistically significant (β = .06 (BBC 90% CI = .01, .11), p=.04). This result indicates that the association between biological maturation (i.e. APHV) and MVPA is only partially mediated and that a

significant proportion of the variance shared between the two constructs remains unexplained.

[Figure 2 near here]

Discussion

The results of the current investigation provide partial support for the hypothesized mediated effects model and supported the contention that advanced (i.e. early) maturation in adolescent girls is associated with lower MVPA. Consistent with previous literature (Jackson et al. 2013), later maturation was found to be associated with higher perceptions of body attractiveness and physical self-worth, which, in turn, predicted greater MVPA. The nature and directions of the path coefficients observed in the hypothesized model were also consistent with those described in previous studies examining the mediated effects of maturation upon physical activity in adolescent girls (Cumming, Standage, et al. 2011). It should be noted, however, that the direct association between maturation and MVPA remained statistically significant when the mediating variables were included in the model. This suggests that perceptions of the physical self may account for some but not all of the variation between maturation and MVPA. The unexplained variance may result from a direct effect of maturation on MVPA or may be a product of variables that are not accounted for in the hypothesized model.

The observed associations among maturation, body attractiveness, and physical self-worth are worthy of further discussion. Girls who mature in advance of their peers appear to view themselves as less physically attractive and, as a consequence, report

lower physical self-worth. Physical appearance is considered an important source of self-worth and esteem in adolescent girls (Harter 2000). A study of over 50 US adolescent girls and boys suggested that body attractiveness was the most common subject of conversation for girls during adolescence and was deemed to be of greater importance than one's success in education and sports (Martin 1996). This observation that perceptions of the physical self are lower in girls who are more advanced in maturation may result from the maturity associated changes in size, shape and physique that accompany puberty. Many of these changes run counter to Western ideals pertaining to attractiveness in females (i.e., preference towards a more linear, lean physique) (Paxton et al. 2005). Girls who mature in advance of their peers will generally experience a more intense pubertal growth spurt. (Malina, Robert M. Bouchard, Claude. Bar-Or 2004) Early maturing girls will also experience these changes at an age when they may not possess the cognitive or emotional skills to respond and/or adapt effectively (Pringle et al. 2017).

The results of the current study are useful from an applied perspective as they identify a potential mechanism through which maturity associated declines in physical activity might be countered. Physical self-worth represents the individual's beliefs, knowledge, values and perceptions pertaining to the body (Fox and Lindwall) and can be modified through personalized feedback education, challenging perceptions and re-evaluation (Manning 2007). A lack of knowledge pertaining to the physiological processes of normal growth and maturation has been documented as a source of anxiety in adolescent girls (Martin 1996). Psychoeducational interventions designed to inform adolescents on the subject of puberty and encourage them to accept it as a normal and attractive part of becoming an adult, may be of value in terms of helping students adapt to

this change more effectively. Such intervention should combine education with the personal reorganization and reinterpretation of body image and related self-perceptions. The intervention should also encourage students to challenge existing stereotypes pertaining to the body and might borrow principles and/or strategies from existing Cognitive Behavioral Therapy interventions (Cash, T. F. 1997). While there is much evidence to support the effectiveness of body-image CBT programs in college aged and adult samples, the efficacy of such interventions in adolescents is less clear. Further research on the design, implementation and efficacy of such strategies, and how they might be incorporated into physical activity programmes for adolescent girls is warranted. Researchers investigating physical activity correlates/determinants and bio-social theories of physical activity/behavior change of adolescents should also consider including timing of biological maturity. Furthermore, investigate whether effect of physical activity interventions varies by biological maturity status, in addition to other important intrapersonal characteristics such as gender, ethnicity and socioeconomic status may also be warranted.

Strengths of the study include a large multi-ethnic female sample and device measured physical activity, with high compliance. However, these findings may not transfer to adolescent boys. Although boys progress through a comparable process, the average age and nature of the physical changes that occur are markedly different (de Guzman and Nishina 2014). For example, early maturity in males is associated with enhanced lean mass resulting in physiological (e.g. strength and power) advantages. Thus, adolescent boys' perceptions of early maturity are likely to be quite different to adolescent girls. However, to date there is a paucity of research investigating this. Unfortunately, our

sample size did not permit us the mediation models to be run by ethnic group (i.e. white British and South Asian). The importance of body attractiveness to overall self-worth and what defines body attractiveness has been shown to vary with culture and social class (Martin 1996). African American girls, for instance, tend to be more satisfied with their bodies than white girls (de Guzman and Nishina 2014). To the authors' knowledge there is a paucity of data on how South Asian girls perceive the physical changes that occur during adolescence. However, there is literature to suggest that South Asian girls may be at more risk for developing a negative body image compared with white British (Bakhshi 2011), but more research with larger samples of South Asian girls is needed. Due to the cross-sectional nature of this study's design it is also not possible to comment on causation. Longitudinal research is required, ideally beginning in late childhood and tracking changes through to late adolescence in order to better understand how physical self-perceptions may mediate relations between maturation and physical activity. It is important to note limitations associated with the method for estimating maturation. The reliability and accuracy of the maturity offset has been shown to vary relative to both age and maturity timing, with errors being greatest in older and younger children, and children who are especially advanced or delayed in maturation (Malina and Kozieł 2014). Lastly, examining a broader range of self-perceptions (e.g. global self-worth, sport competence, strength, physical condition) may have influenced results.

In conclusion, the results of the current study provide partial support for the mediated effects of model of maturity associated variation in physical activity and the hypothesis that advanced maturation in adolescent females is associated with less involvement in MVPA. As a consequence, researchers interested in the study of physical

activity, including the development of targeted interventions for adolescent girls, should consider the measurement of maturation status to explore the potential contribution of biological maturation, including interactions with psychosocial constructs.

References

Bakhshi S. 2011. Women's body image and the role of culture: A review of the literature. Eur J Psychol. 7(2):374–394. doi:10.5964/ejop.v7i2.135.

Baron RM, Kenny DA. 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. J Pers Soc Psychol. 51(6):1173–1182. doi:10.1037/0022-3514.51.6.1173. [accessed 2019 Dec 11]. http://doi.apa.org/getdoi.cfm?doi=10.1037/0022-3514.51.6.1173.

Bryne B. 2001. Structural Equation Modeling with Amos: Basic Concepts, Applications, and Programming. NJ, LEA,: Mahwah.

Cash, T. F. 1997. The Body-Image Workbook: An Eight Step Program for Learning to Like Your Looks. New Harbinger, CA: Oakland.

Cumming SP, Gillison FB, Sherar LB. 2011. Biological maturation as a confounding factor in the relation between chronological age and health-related quality of life in adolescent females. Qual Life Res. 20(2). doi:10.1007/s11136-010-9743-0.

Cumming SP, Sherar LB, Pindus DM, Coelho-e-Silva MJ, Malina RM, Jardine PR. 2012. A biocultural model of maturity-associated variance in adolescent physical activity. Int Rev Sport Exerc Psychol. 5(1). doi:10.1080/1750984X.2011.630481.

Cumming SP, Sherar LB, Smart JE, Rodrigues AMM, Standage M, Gillison FB, Malina RM. 2012. Physical Activity, Physical Self-Concept, and Health-Related Quality of Life of Extreme Early and Late Maturing Adolescent Girls. J Early Adolesc. 32(2). doi:10.1177/0272431610393250.

Cumming SP, Standage M, Loney T, Gammon C, Neville H, Sherar LB, Malina RM. 2011. The mediating role of physical self-concept on relations between biological maturity status and physical activity in adolescent females. J Adolesc. 34(3). doi:10.1016/j.adolescence.2010.06.006.

Edwardson CL, Harrington DM, Yates T, Bodicoat DH, Khunti K, Gorely T, Sherar LB, Edwards RT, Wright C, Harrington K, et al. 2015. A cluster randomised controlled trial to investigate the effectiveness and cost effectiveness of the "Girls Active" intervention: A study protocol. BMC Public Health. 15(1). doi:10.1186/s12889-015-1886-z.

Ekelund U, Sherar L, Cooper A. 2012. Time spent sedentary and active and cardiometabolic risk factors in children - In reply. JAMA - J Am Med Assoc. 307(19).

Fox KR, Lindwall M. Self-esteem and self-perceptions in sport and exercise. In: Routledge Companion to Sport and Exercise Psychology. Routledge. [accessed 2020 Jan 21]. https://www.taylorfrancis.com/books/9781315880198.

Freeman J V., Cole TJ, Chinn S, Jones PRM, White EM, Preece MA. 1995. Cross sectional stature and weight reference curves for the UK, 1990. Arch Dis Child. 73(1):17–24. doi:10.1136/adc.73.1.17.

Guthold R, Stevens GA, Riley LM, Bull FC. 2019 Nov. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. Lancet Child Adolesc Heal. doi:10.1016/S2352-4642(19)30323-2. [accessed 2019 Nov 26]. https://linkinghub.elsevier.com/retrieve/pii/S2352464219303232.

de Guzman NS, Nishina A. 2014. A longitudinal study of body dissatisfaction and pubertal timing in an ethnically diverse adolescent sample. Body Image. 11(1):68–71. doi:10.1016/j.bodyim.2013.11.001. [accessed 2020 Jan 21]. http://www.ncbi.nlm.nih.gov/pubmed/24331829.

Hansen BH, Anderssen SA, Andersen LB, Hildebrand M, Kolle E, Steene-Johannessen J, Kriemler S, Page AS, Puder JJ, Reilly JJ, et al. 2018 Apr 6. Cross-Sectional Associations of Reallocating Time Between Sedentary and Active Behaviours on Cardiometabolic Risk Factors in Young People: An International Children's Accelerometry Database (ICAD) Analysis. Sports Med. doi:10.1007/s40279-018-0909-1. [accessed 2018 Apr 29]. http://link.springer.com/10.1007/s40279-018-0909-1.

Harrington DM, Davies MJ, Bodicoat DH, Charles JM, Chudasama Y V., Gorely T, Khunti K, Plekhanova T, Rowlands A V., Sherar LB, et al. 2018. Effectiveness of the "Girls Active" school-based physical activity programme: A cluster randomised controlled trial. Int J Behav Nutr Phys Act. 15(1):40. doi:10.1186/s12966-018-0664-6.

Harter S. 2000. Is Self-Esteem Only Skin-Deep? The Inextricable Link between Physical Appearance and Self-Esteem. Reclaiming Child Youth. 9(3):133. https://www.researchgate.net/publication/234657515_Is_Self-Esteem_Only_Skin-Deep_The_Inextricable_Link_between_Physical_Appearance_and_Self-Esteem/citation/download.

van Hees VT, Gorzelniak L, Dean León EC, Eder M, Pias M, Taherian S, Ekelund U,

Renström F, Franks PW, Horsch A, et al. 2013. Separating Movement and Gravity Components in an Acceleration Signal and Implications for the Assessment of Human Daily Physical Activity. PLoS One. 8(4). doi:10.1371/journal.pone.0061691.

Hildebrand M, VAN Hees VT, Hansen BH, Ekelund U. 2014. Age group comparability of raw accelerometer output from wrist- and hip-worn monitors. Med Sci Sports Exerc. 46(9):1816–24. doi:10.1249/MSS.0000000000000289. [accessed 2019 Dec 2]. http://www.ncbi.nlm.nih.gov/pubmed/24887173.

Hu LT, Bentler PM. 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Model. 6(1):1–55. doi:10.1080/10705519909540118.

Jackson L, Cumming SP, Drenowatz C, Standage M, Sherar LB, Malina RM. 2013. Biological maturation and physical activity in adolescent British females: The roles of physical self-concept and perceived parental support. Psychol Sport Exerc. 14(4). doi:10.1016/j.psychsport.2013.01.001.

Machado Rodrigues AM, Coelho E Silva MJ, Mota J, Cumming SP, Sherar LB, Neville H, Malina RM. 2010. Confounding effect of biologic maturation on sex differences in physical activity and sedentary behavior in adolescents. Pediatr Exerc Sci. 22(3).

Malina, Robert M. Bouchard, Claude. Bar-Or O. 2004. Growth, Maturation, and Physical Activity. 22nd ed. Champagne, Ill: Human Kinetics. [accessed 2019 Dec 2]. https://books.google.co.uk/books/about/Growth_Maturation_and_Physical_Activity.html?id=VqFcFsykj6EC&redir_esc=y.

Malina RM, Kozieł SM. 2014. Validation of maturity offset in a longitudinal sample of Polish girls. J Sports Sci. 32(14):1374–1382. doi:10.1080/02640414.2014.889846.

Manning MA. 2007. Self-concept and self-esteem in adolescents. Student Serv. 2:11–15.

Martin KA. 1996. Puberty, Sexuality, and the Self: Girls and Boys at Adolescence. New York: Routledge.

McKinnon B, Gariépy G, Sentenac M, Elgar FJ. 2016. Adolescent suicidal behaviours in 32 low- and middle-income countries. Bull World Health Organ. 94(5):340–350F. doi:10.2471/BLT.15.163295. [accessed 2019 Jul 5]. http://www.who.int/entity/bulletin/volumes/94/5/15-163295.pdf.

Migueles, J.H., Rowlands, A.V., Huber, F., Sabia, S., van Hees V. 2019. GGIR: A

Research Community–Driven Open Source R Package for Generating Physical Activity and Sleep Outcomes From Multi-Day Raw Accelerometer Data in: Journal for the Measurement of Physical Behaviour Volume. J Meas Phys Behav. 2(3). [accessed 2020 Mar 6]. https://journals.humankinetics.com/view/journals/jmpb/2/3/article-p188.xml.

Mirwald RL, Baxter-Jones ADG, Bailey DA, Beunen GP. 2002. An assessment of maturity from anthropometric measurements. Med Sci Sports Exerc. 34(4):689–694. doi:10.1249/00005768-200204000-00020.

Paxton SJ, Norris M, Wertheim EH, Durkin SJ, Anderson J. 2005. Body dissatisfaction, dating, and importance of thinness to attractiveness in adolescent girls. Sex Roles. 53(9–10):663–675. doi:10.1007/s11199-005-7732-5.

Pindus DM, Cumming SP, Sherar LB, Gammon C, Coelho e Silva M, Malina RM. 2014. Maturity-Associated Variation in Physical Activity and Health-Related Quality of Life in British Adolescent Girls: Moderating Effects of Peer Acceptance. Int J Behav Med. 21(5). doi:10.1007/s12529-013-9344-8.

Pringle J, Mills KL, McAteer J, Jepson R, Hogg E, Anand N, Blakemore SJ. 2017. The physiology of adolescent sexual behaviour: A systematic review. Cogent Soc Sci. 3(1). doi:10.1080/23311886.2017.1368858.

Schaefer CA, Nigg CR, Hill JO, Brink LA, Browning RC. 2014. Establishing and evaluating wrist cutpoints for the GENEActiv accelerometer in youth. Med Sci Sports Exerc. 46(4):826–33. doi:10.1249/MSS.0000000000000150. [accessed 2019 Dec 2]. http://www.ncbi.nlm.nih.gov/pubmed/24121241.

Shephard RJ. 2003. Limits to the measurement of habitual physical activity by questionnaires. Br J Sports Med. 37(3):197–206. doi:10.1136/bjsm.37.3.197.

Sherar LB, Cumming SP, Eisenmann JC, Baxter-Jones ADG, Malina RM. 2010. Adolescent biological maturity and physical activity: Biology meets behavior. Pediatr Exerc Sci. 22(3). doi:10.1123/pes.22.3.332.

Sherar LB, Esliger DW, Baxter-Jones ADG, Tremblay MS. 2007. Age and gender differences in youth physical activity: Does physical maturity matter? Med Sci Sports Exerc. 39(5). doi:10.1249/mss.0b013e3180335c3c.

Shrout PE, Bolger N. 2002. Mediation in experimental and nonexperimental studies: New procedures and recommendations. Psychol Methods. 7(4):422–445. doi:10.1037/1082-

989X.7.4.422.
Whitehead J. 1995. A study of children's physical self-perceptions using an adapted physical self-perception profile questionnaire. Pediatr Exerc Sci. 7:132–51.

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Table 1. Descriptive statistics for measures of maturation, body size, physical self-perceptions, accelerometer wear time, and physical activity in British girls aged 11 to 14 years (N=1062).

	11years n=194	12years n=403	13years n=354	14years n=111
Chronological age (years)	11.8 (.1)	12.5 (.3)	13.4 (.3)	14.3 (.2)
Predicted age at PHV (years)	12.5 (.7)	12.6 (.8)	12.5 (.8)	12.7 (.8)
Years from APHV (years)	-.7 (.8)	-.1 (.8)	.9 (.9)	1.6 (.9)
Height (cm)	150.9 (7.2)	155.1 (7.6)	159.5(6.9)	161.1 (6.6)
Weight (kg)	43.3 (10.1)	46.4 (10.8)	53.0 (12.8)	55.9 (13.2)
BMI (kg/m^2)	18.8 (3.4)	19.1 (3.5)	20.7 (4.3)	21.5 (4.6)
Physical self-worth	3.5 (.9)	3.4 (.9)	3.1 (.8)	2.9 (.9)
Body attractiveness	2.9 (.9)	2.9 (.9)	2.6 (.8)	2.6 (.9)
Accel wear time (days)	6.9 (.1)	6.9 (.1)	6.9 (.1)	6.9 (.1)
MVPA (mins/day)	39.5 (8.4)	37.2 (8.6)	34.5 (7.8)	33.2 (7.7)

MVPA= moderate -to-vigorous physical activity; APHV= age at peak height velocity; BMI= Body Mass Index

Table 2. Pearson product moment correlations (one-tailed) between measures of maturation, body size, physical self-perceptions, and physical activity in a sample of UK girls aged 11 to 14 years (N=1062).

	1	2	3	4	5	6
1. Predicted APHV						
2. Height	-.63***					
3. Weight	-.87***	.64***				
4. BMI	-.78***	.32***	.93***			
5. Body attractiveness	.25***	-.11***	-.35***	-.38***		
6. Physical self-worth	.24***	-.16***	-.34***	-.35***	.78***	
7. MVPA	.11***	-.29***	-.17***	-.08*	.16***	.22***

* = p <.05; ** = p <.01; *** = p <.001

Figure 1. Hypothesized mediated effects model describing relations among biological maturity, perceived body attractiveness and physical self-worth, and MVPA in adolescent females.

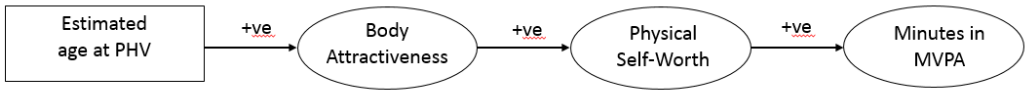
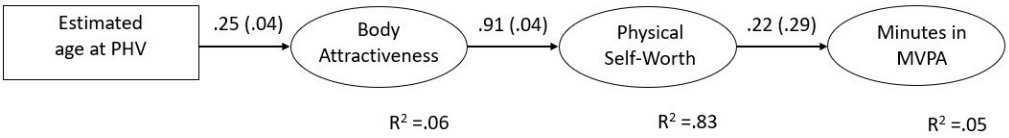


Figure 2. Mediated effects model describing relations among biological maturity, perceived body attractiveness and physical self-worth, and MVPA in adolescent females.



Note. All solid line parameters are significant (p<.05). Standardized Beta coefficients are presented for each parameter with standard errors in parentheses. Squared multiple correlations included for all endogenous factors. Indirect effects were observed between APHV and physical self-worth (β = .28 (BBC 90% CI = .39, 17), P<.001), APHV and MVPA (β = .14 (BBC 90% CI = 22, .08), P<.001), and perceived body attractiveness and MVPA (β = .17 (BBC 90% CI = 25, .10), P<.001). Factors indicators are not included in the model for the purpose of making the presentation less complex.