This item was submitted to [Loughborough's Research Repository](#) by the author.
Items in Figshare are protected by copyright, with all rights reserved, unless otherwise indicated.

Maturity-associated variance in physical activity and health-related quality of life in adolescent females: a mediated effects model

PLEASE CITE THE PUBLISHED VERSION

<http://dx.doi.org/10.1123/jpah.9.1.86>

PUBLISHER

© Human Kinetics

VERSION

SMUR (Submitted Manuscript Under Review)

PUBLISHER STATEMENT

This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at:
<https://creativecommons.org/licenses/by-nc-nd/4.0/>

LICENCE

CC BY-NC-ND 4.0

REPOSITORY RECORD

Smart, Joan E. Hunter, Sean P. Cumming, Lauren B. Sherar, Martyn Standage, Helen Neville, and Robert M. Malina. 2019. "Maturity-associated Variance in Physical Activity and Health-related Quality of Life in Adolescent Females: A Mediated Effects Model". figshare. <https://hdl.handle.net/2134/22573>.

1

2 Maturity Associated Variance in Physical Activity and Health-Related Quality of Life in

3 Adolescent Females: A Mediated Effects Model.

4

5

6

Submitted as Original Research

7

8

9

10

11

12

13

14

15

16

17

18

19

20 Key Words: Adolescence, Exercise, Physical Self-Concept

21 Abstract Word Count: 144

22 Manuscript Word Count: 4179

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24

Abstract

Background: This study tested a mediated effects model of psychological and behavioral adaptation to puberty within the context of physical activity (PA).

Methods: Biological maturity status, physical self-concept, PA and health-related quality of life (HRQoL) were assessed in 222 female British year 7-9 pupils (M age=12.7 years, SD=.8).

Results: Structural equation modeling using maximum likelihood estimation and bootstrapping procedures supported the hypothesized model. Maturation status was inversely related to perceptions of sport competence, body attractiveness, and physical condition; and indirectly and inversely related to physical self-worth, PA and HRQoL. Examination of the bootstrap-generated bias-corrected confidence intervals representing the direct and indirect paths between suggested that physical self-concept partially mediated the relations between maturity status and PA, and maturity status and HRQoL.

Conclusions: Evidence supports the contention that perceptions of the physical self partially mediate relations maturity, PA, and HRQoL in adolescent females.

1 Maturity Associated Variance in Physical Activity and Health-Related Quality of Life in
2 Adolescent Females: A Mediated Effects Model.

3 Physical activity (PA) plays an important role in the promotion and maintenance of
4 health. Individuals who regularly engage in moderate-to-vigorous bouts of PA
5 demonstrate improved functional capacity and are at less risk for many degenerative
6 diseases and psychological disorders (e.g., hypertension, type II diabetes, coronary heart
7 disease, depression and anxiety) ¹. PA is also considered a prerequisite for positive
8 physical and psychological development ². To ensure the health benefits afforded through
9 regular involvement in PA, children should be encouraged to be active from an early age.
10 However, evidence suggests that over the past four decades children are becoming less
11 active in many forms of PA, including physical education , active transport, and leisure-
12 time activities ³.

13 Those involved in the study and promotion of PA in youth have generally
14 focussed on the roles that psychosocial and environmental factors play in relation to PA ⁴.
15 Although factors, such factors undoubtedly contribute to children's involvement in PA, it
16 is increasingly evident that a true explanation of PA in youth resides in the independent
17 and interactive effects of various biological, psychosocial, and environmental factors ^{5,6}.
18 Accordingly, it has been suggested that researchers re-examine the biological basis of
19 PA with the intention of informing both theory and practice ⁵⁻⁸. PA is, after all, a
20 biological process that exists within a complex cultural context in which value, meaning,
21 and sanctions are ascribed to it ⁸.

22 A number of biological factors and processes have been identified as potential
23 contributors to variance in PA, including biological maturation ⁶. Biological maturation

1 refers to progression towards the mature (i.e., adult) state, can be considered in terms of
 2 tempo and/or timing ², and may be particularly relevant to the study of PA in youth ⁶.
 3 Tempo refers to the rate at which maturation progresses, whereas timing refers to the time
 4 at which certain maturity-related events occur (e.g., age-at-menarche or peak height
 5 velocity). Children of the same chronological age can demonstrate considerable variation
 6 in biological maturity, with some maturing much earlier or later than others.

7 There is good reason to believe that variance in biological maturation may
 8 contribute to PA in adolescence, particularly in females. First, the observation that
 9 individuals become less active as they progress towards the mature state is a consistent
 10 finding in pediatric exercise science ⁶. Second, evidence suggests that sex-related
 11 variance in biological maturation explains differences in the PA of boys and girls of the
 12 same chronological age ⁹. Third, the physical characteristics associated with advanced
 13 maturation in girls (i.e., greater pubertal gains in height, weight, and weight-for-height,
 14 with gains in weight a result of increases in absolute and proportional fat-mass) may be
 15 less conducive to successful involvement in PA ⁷⁻⁸, especially in activities that emphasise
 16 endurance, weight-bearing, and/or aesthetics. Finally, girls who are advanced in maturity
 17 status are more likely to socialize with older, and less active, peer groups ¹⁰.

18 In accordance with extant literature ⁹, one would predict an inverse relation
 19 between maturity status and PA in this adolescent females. Research examining this
 20 contention has, however, produced equivocal results ⁹. Whereas some studies have
 21 shown late maturing females to be more active than early maturing females ^{11, 12}, others
 22 have found no relation between maturity status and PA ^{13, 14}, or that early maturing girls
 23 were more active ¹⁵. Lack of consistency in these findings has been attributed to a number

1 of factors, including a failure to address factors that may moderate or mediate relations
 2 between maturation and PA, sample size, and construct measurement ⁹. Whereas some
 3 studies have relied on subjective measures of PA and maturation, others have employed a
 4 combination of objective and subjective measures, or objective measures exclusively.
 5 For a more comprehensive review and discussion of research pertaining to maturity
 6 associated variance in PA see Sherar et al ⁹.

7 In an attempt to explain relations between maturation status and PA in adolescent
 8 girls, Cumming and colleagues ¹⁶ proposed and tested a mediated effects model of
 9 maturity associated variance in PA. The model, based on a Mediated Effects Model of
 10 Psychological and Behavioural Adaptation to Puberty described by Petersen and Taylor
 11 ¹⁷, hypothesized that relations between maturation status and PA were mediated by
 12 physical self-concept (i.e., the feelings and beliefs that one has towards the physical self).
 13 More specifically, it predicted that maturity status would be inversely related with
 14 perceptions of physical self-concept, which would, in turn, positively predict involvement
 15 in PA. Structural equation modelling employing bootstrapping procedures indicated
 16 strong support for the model (CFI = .95; SRMR = .08) in a sample of adolescent British
 17 female students aged 12-15 years. Early maturing girls held lower perceptions of body
 18 attractiveness, sport competence, physical conditioning (but not strength) and overall
 19 physical self-worth, which, in turn, predicted less involvement in PA. An indirect inverse
 20 relation between maturation and PA was observed, through physical self-concept,
 21 supporting the contention that physical self-concept mediates relations between the
 22 aforementioned constructs.

Although the mediated effects model serves as a promising framework from which to study and understand maturity associated variance in PA, it has, to date, received limited empirical attention. Accordingly, the purpose of our investigation was to test the aforementioned model on a separate sample and extend it to include a measure of health-related quality of life (HRQoL) (Figure 1). There is good reason to believe that maturation may be related to HRQoL in adolescent females. Due to greater gains in absolute and proportional fat-mass, early maturing girls are more likely to be classified as overweight or obese. Overweight and obese youth tend to report lower levels of HRQoL when compared with their normal weight peers¹⁸⁻²¹. Early maturation also is associated with a more negative body image and physical self-concept²² and less involvement in health promoting activities such as exercise²³ and competitive sports²⁴. Early maturing girls also report more negative initial experiences to puberty (e.g. inconvenience, ambivalence and confusion;²⁵ and increased distress, anxiety, depression, and psychosomatic symptoms^{22, 26-28}. Early maturity is also linked with early substance abuse²⁹, alcohol abuse³⁰ and early sexual initiation³¹.

In accordance with extant literature pertaining to maturation, PA and health in adolescent girls^{2, 13, 32}, the hypothesized mediated effects model (Figure 1) predicted that (i) advanced maturation would predict lower perceptions of sport competence, body attractiveness and physical condition, but higher perceptions of strength; (ii) that perceptions of sport competence, body attractiveness, physical condition and strength would, in turn, positively predict physical self-worth; (iii) that physical self-worth would positively predict involvement in PA; (iv) that PA would positively predict HRQoL (v) that biological maturity status would indirectly predict variance in both physical self-

worth, PA, and HRQoL; (vi) and that physical self-worth would directly and indirectly (via PA) predict HRQoL.

Method

Participants

Participants were 222 female Year 7 through 9 pupils from a single-sex state funded school in the South West of England (M age = 12.7, SD = .8 years; range = 10-14 years). The study was approved by the School for Health's research ethics committee. Written consent was obtained from the Head Teacher, who acted in *loco parentis*. Parents were informed of the research by post and asked to provide passive consent (i.e., contact the school/researchers if they *did not* wish their child to take part). Verbal consent was obtained from pupils.

Field Protocol

Prior to the start of a Physical Education class, participants completed a series of self-report questionnaires, including the Physical Activity Questionnaire for Adolescents (PAQ-A)³³, the Children and Youth's Physical Self-Perceptions Scale (CY-PSPP)³⁴, and the Kidscreen-10 HRQoL Questionnaire (K-10). Height and weight were measured using standardized procedures³⁵. Chronological age in decimals was calculated as the difference between date of birth and date of measurement.

Measures

Estimated Maturity Status. Percentage of predicted mature (adult) height attained at the time of measurement was used as a non-invasive estimate of biological maturity status. This method assumes that among youth of the same chronological age, the child who is closer to his/her predicted mature height is biologically older (i.e., more advanced

in maturity) than the individual who is further removed from his/her predicted adult height than expected for age ². For example, the mean percentage of mature height attained in girls of the Berkeley Guidance Study at the age of 12 years is 93% ³⁶. A girl who has attained 98% of her predicted adult height at 12 years would be considered biologically older than a girl of the same chronological age who has attained 86% of her predicted adult height.

The Khamis-Roche method ³⁷ was used to predict the mature height from current age, height and weight of the participant and midparent height (average height of biological parents). The median error bound (median absolute deviation) between actual and predicted mature height at 18 years of age is 2.2 cm in males and 1.7 cm in females ³⁷. Biological parents of the participants reported their heights. As adults generally overestimate height, the self-reported height of each parent was adjusted for over estimation using an equation constructed from over 1000 measured and estimated heights of adults ³⁸.

Estimated biological maturity status was expressed as a z-score, using the percentage of predicted adult height attained at the time of measurement, and half-year age- and sex-specific means and standard deviations from the Berkeley Guidance Study ³⁶. The reference sample was selected on four counts: first, mean heights and weights of boys and girls aged 13-15 years in the guidance sample are similar to current United Kingdom reference values ³⁹; second means and standard deviations in the guidance sample are reported at half year intervals; third, the Khamis-Roche method for predicting adult height uses the same half-year age intervals as the Guidance study sample; fourth, the mean percentages of predicted adult height attained at all whole years (e.g., 11.0

years, 12.0 years) are very similar to those in a more recent sample³⁷. The Khamis-Roche method for estimating biological maturation has been used in a number of studies with US and British youth⁴⁰⁻⁴³ and has been validated against established indicators of maturity (skeletal age) in youth American football players⁴⁴.

Physical Activity. The Physical Activity Questionnaire for Adolescents (PAQ-A)³³ was used to assess involvement in PA. The PAQ-A is an eight item instrument that requires participants to indicate how frequently they engaged in various activities over a seven day recall period. The PAQ-A has demonstrated adequate levels of validity and reliability⁴⁵. In the current sample the PAQ-A demonstrated an acceptable level of internal consistency (Cronbach's alpha = .79).

Physical Self-Concept. The Children and Youths' Physical Self-Perception Profile (CY-PSPP)³⁴ was used to assess the physical self-concept. This scale assesses 6 dimensions of the self (i.e., sport competence, physical condition, body attractiveness, strength, physical self-worth, and general self-worth) and requires participants to respond to a series of 36 items that are structured in an alternative response format. Theoretically, the physical self-worth dimension is considered a higher-order construct, with sport competence, physical condition, body attractiveness, and strength serving as lower-order constructs that contribute to physical self-worth. All dimensions of the CY-PSPP, with the exception of general self-worth were included in the current analyses. The CY-PSPP has previously demonstrated acceptable levels of construct validity and reliability⁴⁶. All dimensions of the CY-PSPP used in the current study demonstrated adequate levels of internal consistency (Cronbach's alphas ranged from .89-.93).

Health-Related Quality of Life. HRQoL was assessed using the Kidscreen-10 HRQoL Questionnaire (K-10). The inventory contains ten items comprising psychological, physical and social dimensions of HRQoL. Based on a one-week recall period, pupils estimated the intensity of their feelings towards each item using a five-point Likert scale. Rasch scores were calculated, after the reversal of negatively formulated items, and converted into t-values with a scale mean of 50 and a standard deviation of 10, based on data from the Kidscreen international survey sample (The Kidscreen Group, 2006). Higher scores reflect superior HRQoL. Good test re-test reliability ($r = 0.73$; ICC = 0.72) and high convergent validity with other generic HRQoL instruments, including the Youth Quality of Life Instrument-Surveillance Version ($r = 0.61$), was supported by The Kidscreen Group (2006). Acceptable internal consistency was exhibited in the current sample (Cronbach's $\alpha = .79$).

Statistical Analyses

Descriptive statistics by age group were calculated for body size, percentage of predicted mature height, maturity status, physical self-concept, PA, and HRQoL. Pearson product moment correlations (one-tailed) were calculated to examine relations among the variables of interest. Structural equation modeling, utilizing maximum likelihood estimation and bootstrapping procedures, was used to test the hypothesized model concerning relations among maturational status, physical self-concept, PA, and HRQoL. To determine the adequacy of model fit, a 2-index presentation strategy advanced by Hu and Bentler⁴⁷ 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). SRMR values close to .08 (or lower) are indicative of a well-specified model⁴⁷

whereas CFI values of over .90 and .95 reflect acceptable and excellent fit between the model and data, respectively⁴⁷. In accordance with recent recommendations⁴⁸, 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

Descriptive statistics for chronological age, body size, estimated maturity status, physical self-concept, PA and HRQoL are summarized by age group in Table 1. Mean values for maturity status z-scores approximated, or fell just below, 0 in the 11, 12, and 13 year old age groups and were lowest in the 14 year old age group. Compared to UK reference values³⁹, mean heights fell between the 50th and 75th centiles for age in each age group. Mean values for weight and BMI fell between the 50th and 75th centiles at age 12 and 14, yet approximated the 75th centile at 11 and 13 years. Mean values for BMI approximated or fell just below the 75th centile in all age groups. Mean values for HRQoL fell below the International Standard in all age groups.

Correlations

Relations between biological maturity status, physical self-concept, PA and HRQoL are presented in Table 2. As predicted, estimated biological maturity status was negatively associated with sport competence, physical condition, body attractiveness, physical self-worth, PA, and HRQoL. Though positive, the relation between maturation status and strength was non-significant. PA was positively associated with HRQoL and all dimensions of the CY-PSPP.

The Mediated Effects Model

Given the complexity of the hypothesized model, a parceling strategy⁴⁹ was employed to limit the number of estimated parameters. The six items of each subscale of the CY-PSPP were parceled into three indicators of a latent variable that reflected the subscale. The three items with the highest item-to-construct loadings were used to anchor each of the three indicators. The three items with the next highest loadings were then added to the anchors in reverse order (e.g., 1st & 6th, 2nd & 5th, & 3rd & 4th, highest loading items parcelled together), thus increasing the likelihood that parcels were balanced in terms of difficulty and discrimination and limiting experimenter bias⁴⁹. The sum of the two items was used to create each indicator of the latent variable (i.e. parceled item). Using the same procedures, the eight items representing the PAQ-A were parceled into four indicators of a latent variable that reflected PA. Similarly, the ten items representing HRQoL were parceled into five indicators of a latent variable that represented that construct. For a more in-depth explanation of parceling process and its advantages see the review by Little and colleagues⁴⁹.

In light of the moderate-to-strong correlations among the sub-dimensions of the CY-PSPP, covariance paths between the disturbance terms of the latent factors (i.e., sport competence, physical condition, body attractiveness, strength) were added to the hypothesized model. These paths specify the interrelations between the various sub-dimensions and the shared variance not accounted for by the predictor variable.

Employing AMOS 16.0 software, structural equation modelling (SEM) using maximum likelihood estimation was used to test the fit of the hypothesized model. Inspection of the Mardia's Coefficient value (63.46, $p < .001$) revealed the data to depart from multivariate normality. Thus, the SEM analysis was conducted using the

bootstrapping procedure with 5000 bootstrap replication samples to provide a more accurate assessment of the parameter estimates' stability⁵⁰.

The model fit indices suggested a good fit between the proposed model and the data (SRMR = .07; CFI = .95). The standardized Beta coefficients, standard errors, and squared multiple correlations (SMC) associated with the model are presented in Figure 2.

As predicted, biological maturity status negatively predicted perceptions of sport competence ($\beta = -.19$, $p < .01$), physical condition ($\beta = -.29$, $p < .001$) and body attractiveness ($\beta = -.35$, $p < .001$). Maturity status was, however, unrelated to perceived strength.

Perceptions of sport competence ($\beta = .39$, $p < .01$) and body attractiveness ($\beta = .58$, $p < .001$), but not physical condition or strength, predicted physical self-worth. In turn, physical self-worth positively predicted involvement in PA ($\beta = .50$, $p < .001$) and HRQoL ($\beta = .67$, $p < .001$). Contrary to expectations, PA was unrelated to HRQoL. Finally, maturity status was found to be indirectly related to physical self-worth ($\beta = -.28$ (90% CI $\pm .11$), $p < .001$), PA ($\beta = -.14$ (90% CI $\pm .08$), $p < .001$), and HRQoL ($\beta = -.17$ (90% CI $\pm .08$), $p < .001$). An indirect relation between physical self-worth and HRQoL was not observed ($\beta = -.06$ (90% CI $\pm .12$), $p > .05$).

A version of Baron and Kenny's method for testing mediational hypotheses⁵¹ adapted for structural equation modelling⁵² was employed to test for mediation in the indirect effects. Accordingly, bootstrap-generated bias-corrected confidence intervals were used to estimate the standardized path coefficients representing the direct effects, with and without the inclusion of the mediating variables. Without the mediating variables the direct path coefficients between maturity and physical self-worth ($\beta = -.26$ (BBC 90% CI = $-.38, -.14$), $p < .001$), and maturity and PA ($\beta = -.19$ (BBC 90% CI = $-.33,$

-.06), $p < .01$), and maturity and HRQoL ($\beta = -.15$ (BBC 90% CI = $-.30, .00$), $p = .05$) were negative and significant. However, when the mediating variables were included in the model the path coefficients representing the direct effects between maturity and physical self-worth ($\beta = .04$ (BBC 90% CI = $-.06, .14$), $p = .39$), maturity and PA ($\beta = -.07$ (BBC 90% CI = $-.15, .07$), $p = .32$), and maturity and HRQoL ($\beta = .00$ (BBC 90% CI = $-.15, .15$), $p = .99$) were all attenuated and non-significant. Collectively, these results suggest that the indirect effect between maturity and physical HRQoL was fully mediated, and that the indirect effects between maturity and physical self-worth, and maturity and PA were partially mediated.¹ Inspection of the modification indices and standardized residuals associated with the hypothesized models did not indicate any improvements to the model that were theoretically or substantively justified.

Discussion

The results of this study provide partial support for the hypothesized mediated effects model and the contention that advanced maturation in adolescent girls is associated with less involvement in PA^{11, 12}. Specifically, physical self-concept was found to partially mediate an inverse relation between maturity status and PA. The magnitude and direction of the path coefficients in the hypothesized model were consistent with those described in the mediated effects model presented by Cumming and colleagues¹⁶. Advanced maturation was associated with lower perceptions of body attractiveness, physical condition and sport competence, though no relation was observed with perceived strength. Perceptions of body attractiveness and sport competence, but

¹ At the request of a reviewer, a model specifying direct paths from a potential covariate (viz., chronological age) was analyzed to examine any potential effects of this variable on the paths shown in Figure 2. The direct and indirect path coefficients remained significant, indicating that they did not differ as a function of chronological age.

1 not strength or physical condition, served as positive predictors of physical self-worth
2 which, in turn, predicted greater involvement in PA.

3 The current model advanced the original model ¹⁶ by including HRQoL as
4 endogenous latent variable. As predicted, HRQoL was found to be positively related
5 physical self-worth and indirectly and inversely related to maturity status. Physical self-
6 concept and PA were found to fully mediate the inverse relation between maturation
7 status and HRQoL, further highlighting the potential role that perceptions of the self and
8 PA may play in explaining relations between maturation status and HRQoL in adolescent
9 females. Future research should explore the independent and interactive effects of
10 maturation, physical self-concept and PA in relation to a wider range of health outcomes
11 (e.g., smoking, drinking, diet, sexual behavior). Contrary to expectations, PA was found
12 to be unrelated to HRQoL. This result was somewhat surprising, as previous research has
13 reported positive relations between these constructs ⁵³.

14 The comparatively strong relations among maturation, body attractiveness, and
15 physical self-worth are worthy of discussion. Maturity-associated changes in physical
16 appearance (e.g., body size, composition, physique, development of secondary sex
17 characteristics) may be of greater importance to adolescent females than changes in
18 functional capacity (e.g., sport competence, physical condition, strength). (9). Physical
19 appearance is recognized as the most salient source of self-worth and esteem in
20 adolescent girls ⁵⁴. A qualitative study of over 50 US adolescent girls and boys revealed
21 that the subject of body attractiveness dominated girls conversations during adolescence
22 and was considered to be of greater importance than accomplishments in achievement

domains such as education and sports⁵⁵. Strength and physical condition may also be less salient as sources of self-worth among adolescent females than they are in males⁵⁶.

The mediated effects model described by Petersen and Taylor¹⁷ presents an appealing multidisciplinary framework through which maturity-associated variation in health related behaviors can be studied. The model also affords an ideal framework from which to examine the potential influence of social and environmental factors. For example, the degree to which maturation and physical self-concept impact involvement in PA, might be moderated by social support (e.g., peer or parental), cultural ideals, or the availability of activity related resources (i.e., parks, leisure centers). Although the impact of moderating factors was not examined in the current study, future researchers should seek to explore and validate this aspect of Petersen and Taylor's model¹⁷.

From a practical perspective, Petersen and Taylor's¹⁷ model identifies a means through which maturity associated declines in PA and HRQoL might be countered (i.e., physical self-concept, social support). A lack of subjective and cognitive knowledge with regards to the female body and the processes of growth and maturation has been documented as a source of anxiety in adolescent girls⁵⁵. Interventions designed to educate students on the processes of growth and maturation, and/or encourage them to view puberty as a normal and attractive consequence of becoming an adult, may help students adapt more positively to pubertal changes in health and behavior. Such interventions would undoubtedly require a combination of education and the personal reorganization and reinterpretation of body image and related self-concepts, and might mirror or develop from existing interventions such as Cash's body-image Cognitive Behavioral Therapy (CBT) program⁵⁷. Although there is much evidence that body-image

CBT programs are effective in collegiate and adult samples, there is a paucity of literature examining the efficacy of such interventions in adolescents⁵⁸. Most interventions seeking to promote positive change in adolescents' physical self-concept have limited their strategies to the promotion of exercise (Fox, 2000). Though greater involvement in exercise can undoubtedly enhance physical self-concept, such interventions are limited in that they do not challenge the beliefs and perceptions that underpin physical self-concept.

It is important to recognize a number of limitations associated with the current study. First, the results are limited to adolescent girls living in the Southwest of England. Relations among the variables of interest might vary with age, social circumstance, and culture. For example, body attractiveness is considered a more salient source of self-worth in working class girls⁵⁵, and African American girls tend to be more satisfied with their bodies than white girls⁵⁹. Second, inferences regarding cause and effect relations cannot be made due to the study's cross-sectional design. To obtain more precise information about how physical self-perceptions might mediate relations between maturation and PA it, longitudinal research is required, ideally beginning in late childhood and tracking changes through to late adolescence. Third, the method for estimating maturity status was derived from data collected in the United States. British and American boys and girls aged 9-15 years present very similar mean heights and weights⁶⁰ (<http://www.cdc.gov/growthcharts>), however, further research is required to validate the formulae in British samples. Although mean estimates of maturity status were generally 'on-time', the mean values suggested a slight delay in maturity status in the oldest age group. This may reflect the relatively smaller group sizes or a tendency for older early maturing girls to opt out of studies that require measurements of weight.

1 Finally, self-report measures of PA rely on the participant's memory to assess activity
2 levels and can potentially be influenced by socially desirability. Despite these limitations,
3 the PAQ-A is considered a valid, low cost, and easy to use measures of activity that is
4 well suited for use within youth^{33, 45}.

5 In summary, this study supports the mediated effects of model of maturity
6 associated variation in PA¹⁶ and the contentions that advanced maturation in adolescent
7 females is associated with less involvement and PA and lower HRQoL. Accordingly,
8 researchers PA and HRQoL in youth would do well to consider the contribution of
9 biological maturity status and its potential role as a confounding and/or masking
10 variable⁶¹.

11

References

1. Department of Health Physical Activity Health Improvement and Prevention. *At least five a week: Evidence on the impact of physical activity and its relationship to health*. London: Department of Health; 2004.
2. Malina R. M., Bouchard C., Bar-Or O. *Growth maturation and physical activity*. Champaign, IL: Human Kinetics 2004.
3. Malina R. M., Katzmarzyk P. T. Physical activity and fitness in an international growth standard for preadolescent and adolescent children. *Food and Nutrition Bulletin*. Dec 2006;27:S295-S313.
4. Cumming S. P., Riddoch C. Physical activity, physical fitness, and health: Current concepts. In: Armstrong N, Van Mechelen W, eds. *Paediatric exercise science and medicine*: Oxford University Press; 2009:327-338.
5. Rowland T. W. The biological basis of physical activity. *Medicine and Science in Sports and Exercise*. 1998;30:392-399.
6. Eisenmann J. C., Wickel E. E. Biology of physical activity in children: Revisited. *Pediatric Exercise Science*. 2009;21:257-272.
7. Katzmarzyk P. T., Baur L. A., Blair S. N., et al. International conference on physical activity and obesity in children: Summary statement and recommendations. *International Journal of Pediatric Obesity*. 2008;1:1-19.
8. Malina R. M. Biocultural factors in developing physical activity levels. In: Smith AL, Biddle SJH, eds. *Youth physical activity and inactivity*. Champaign, Ill.: Human Kinetics; 2008:141-166.
9. Sherar L. B., Cumming S. P., Eisenmann J. C., et al. Adolescent biological maturity and physical activity: Biology meets behaviour *Pediatric Exercise Science*. in press.
10. Caspi A., Moffitt T. E. Individual differences are accentuated during periods of social change: The sample case of girls at puberty. *Journal of Personality and Social Psychology*. 1991;61:157-168.
11. Riddoch C., Mattocks C., Deere K., et al. Objective measurement of levels and patterns of physical activity. *Archives of Disease in Childhood*. 2007;92:963-969.
12. Davison K. K., Werder J. L., Trost S. G., et al. Why are early maturing girls less active? Links between pubertal development, psychological well-being, and physical activity among girls at ages 11 and 13. *Social Science and Medicine*. 2007;64:2391-2404.
13. Niven A. G., Fawkner S. G., Knowles A., et al. Maturation differences in physical self-perceptions and the relationship with physical activity in early adolescent girls. *Pediatric Exercise Science*. 2007;19:472-480.
14. Wickel E. E., Eisenmann J. C. Maturity-related differences in physical activity among 13-14- year old adolescents. *Pediatric Exercise Science*. 2007;19:384-392.
15. van Jaarsveld C. H. M., Fidler J. A., Simon A. E., et al. Persistent impact of pubertal timing on trends in smoking, food choice, activity, and stress in adolescence. *Psychosomatic Medicine*. Oct 2007;69:798-806.
16. Cumming S. P., Standage M., Loney T., et al. The mediation effect of physical self-concept on relations between biological maturity status and physical activity in adolescent females. *Journal of Adolescence*. in press.

- 1 **17.** Petersen A. C., Taylor B. The biological approach to adolescence: Biological
2 change and psychological adaptation. In: Adelson J, ed. *Handbook of adolescent*
3 *psychology*. New York: Wiley-Interscience; 1980:117-155.
- 4 **18.** Friedlander S. L., Larkin E. K., Rosen C. L., et al. Decreased quality of life
5 associated with obesity in school-aged children. *Archives of Pediatrics &*
6 *Adolescent Medicine*. Dec 2003;157:1206-1211.
- 7 **19.** Schwimmer J. B., Burwinkle T. M., Varni J. W. Health-related quality of life of
8 severely obese children and adolescents. *Journal of the American Medical*
9 *Association*. Apr 9 2003;289:1813-1819.
- 10 **20.** Swallen K. C., Reither E. N., Haas S. A., et al. Overweight, obesity, and health-
11 related quality of life among adolescents: The national longitudinal study of
12 adolescent health. *Pediatrics*. Feb 2005;115:340-347.
- 13 **21.** Williams J., Wake M., Hesketh K., et al. Health-related quality of life of
14 overweight and obese children. *Journal of the American Medical Association*.
15 2005;293:70-76.
- 16 **22.** Graber J. A., Brooks-Gunn J., Warren M. P. The vulnerable transition: Puberty
17 and the development of eating pathology and negative mood. *Womens Health*
18 *Issues*. 1999;9:107-114.
- 19 **23.** Cumming S. P., Standage M., Gillison F., et al. Sex differences in exercise
20 behavior during adolescence: Is biological maturation a confounding factor?
21 *Journal of Adolescent Health*. May 2008;42:480-485.
- 22 **24.** Malina R. M. The young athlete: Biological growth and maturation in a
23 biocultural context. In: Smoll FL, Smith RE, eds. *Children and youth in sport: A*
24 *biopsychosocial perspective*. 2nd ed. Dubuque, IA: Kendall/Hunt; 2002:261-292.
- 25 **25.** Ruble D. N., Brooks-Gunn J. The experience of menarche. *Child Dev*.
26 1982;53:1557-1566.
- 27 **26.** Kaltiala-Heino R., Kosunen E., Rimpela M. Pubertal timing, sexual behaviour and
28 self-reported depression in middle adolescence. *Journal of Adolescence*. Oct
29 2003;26:531-545.
- 30 **27.** Kaltiala-Heino R., Marttunen M., Rantanen P., et al. Early puberty is associated
31 with mental health problems in middle adolescence. *Soc.Sci Med*. 2003;57:1055-
32 1064.
- 33 **28.** Laitinen-Krispijn S., Van der E. J., Hazebroek-Kampschreur A. A., et al. Pubertal
34 maturation and the development of behavioural and emotional problems in early
35 adolescence. *Acta Psychiatr Scand*. 1999;99:16-25.
- 36 **29.** Dick D. M., Rose R. J., Viken R. J., et al. Pubertal timing and substance use:
37 Associations between and within families across late adolescence. *Dev.Psychol*.
38 2000;36:180-189.
- 39 **30.** Costello E. J., Sung M., Worthman C., et al. Pubertal maturation and the
40 development of alcohol use and abuse. *Drug Alcohol Depend*. 2007;88 Suppl
41 1:S50-9. Epub; 2007 Feb 1.:S50-S59.
- 42 **31.** Brown J. D., Halpern C. T., L'Engle K. L. Mass media as a sexual super peer for
43 early maturing girls. *J Adolesc.Health*. 2005;36:420-427.
- 44 **32.** Davison K. K., Werder J. L., Trost S. G., et al. Why are early maturing girls less
45 active? Links between pubertal development, psychological well-being, and

- 1 physical activity among girls at ages 11 and 13. *Social Science and Medicine*.
2 2007;64:2391-2404.
- 3 **33.** Kowalski K. C., Crocker P. R. E., Donen R. M. The physical activity
4 questionnaire for older children (paq-c) and adolescents (paq-a) manual.2004,
5 University of Saskatchewan, Saskatoon, CA.
- 6 **34.** Whitehead J. R. A study of children's physical self-perceptions using an adapted
7 physical self-perception profile questionnaire. *Pediatric Exercise Science*.
8 1995;7:132-150.
- 9 **35.** Malina R. M. Anthropometry. In: P.J. M, Foster C, eds. *Physiological assessment*
10 *of human fitness*1995:205-219.
- 11 **36.** Bayer L. M., Bayley N. *Growth diagnosis: Selected methods for interpreting and*
12 *predicting development from one year to maturity*. Chicago: University of
13 Chicago Press; 1959.
- 14 **37.** Khamis H. J., Roche A. F. Predicting adult height without using skeletal age: The
15 khamis-roche method. *Pediatrics*. 1994;94:504-507 (*Pediatrics*, 595, 457, 1995
16 for the corrected version of the tables).
- 17 **38.** Epstein L., Valoski A. M., Kalarchian M. A., et al. Do children lose and maintain
18 weight easier than adults? A comparison of child and parent weight changes from
19 six months to ten years. *Obesity Research*. 1995;3:411-417.
- 20 **39.** Freeman J. V., Cole T. J., Chinn S., et al. Cross-sectional stature and weight
21 reference curves for the uk. *Archives of Disease in Childhood*. 1995;73:17-24.
- 22 **40.** Malina R. M., Morano P. J., Barron M., et al. Growth status and estimated growth
23 rate of youth football players: A community-based study. *Clinical Journal of*
24 *Sport Medicine*. May 2005;15:125-132.
- 25 **41.** Cumming S. P., Battista R. A., Standage M., et al. Estimated maturity status and
26 perceptions of adult autonomy support in youth soccer players. *Journal of Sports*
27 *Sciences*. Oct 2006;24:1039-1046.
- 28 **42.** Malina R. M., Morano P. J., Barron M. A., et al. Incidence and player risk factors
29 for iinjury in youth football. *Clinical Journal of Sports Medicine*. 2006;3:214-222.
- 30 **43.** Sweet S. L., Dompier T. P., Stoneberg K. N., et al. Self-reported parent stature is
31 acceptable in estimates of maturity status in youth soccer players. *Journal of*
32 *Athletic Training*. 2002;4:S-129.
- 33 **44.** Malina R. M., Dompier T. P., Powell J. W., et al. Validation of a noninvasive
34 maturity estimate relative to skeletal age in youth football players. *Clinical*
35 *Journal of Sport Medicine*. Sep 2007;17:362-368.
- 36 **45.** Kowalski K. C., Crocker P. R. E., Kowalski N. P. Convergent validity of the
37 physical activity questionnaire for adolescents. *Pediatric Exercise Science*.
38 1997;9:342-352.
- 39 **46.** Eklund R. C., Whitehead J. R., Welk G. J. Validity of the children and youth
40 physical self-perception profile: A confirmatory factor analysis. *Research*
41 *Quarterly for Exercise and Sport*. Sep 1997;68:249-256.
- 42 **47.** Hu L., Bentler P. Cut off criteria for fit indexes in covariance structure analysis:
43 Conventional criteria versus new alternatives. *Structural Equation Modeling*.
44 1999;6:1-55.

- 1 **48.** MacKinnon D. P., Lockwood C. M., Williams J. Confidence limits for the indirect
2 effect: Distribution of the product and resampling methods. *Multivariate*
3 *Behavioral Research*. 2004;39:99-128.
- 4 **49.** Little T. D., Cunningham W. A., Shahar G., et al. To parcel or not to parcel:
5 Exploring the question, weighing the merits. *Structural Equation Modeling*.
6 2002;9:151-173.
- 7 **50.** Byrne B. *Structural equation modeling with amos: Basic concepts, applications,*
8 *and programming*. Mahwah, NJ: LEA; 2001.
- 9 **51.** Baron R. M., Kenny D. A. The moderator-mediator variable distinction in social
10 psychological research: Conceptual, strategic and statistical considerations.
11 *Journal of Personality and Social Psychology*. 1986;51:1173-1182.
- 12 **52.** Shrout P. E., Bolger N. Mediation in experimental and nonexperimental studies:
13 New procedures and recommendations. *Psychological Methods*. 2002;7:422-445.
- 14 **53.** Vuillemin A., Boini S., Bertrais S., et al. Leisure time physical activity and
15 health-related quality of life *Preventive Medicine*. 2005;41:562-569.
- 16 **54.** Page A., Fox K. Adolescent weight-management and the physical self. In: Fox K,
17 ed. *The physical self: From motivation to well-being*. Champaign, IL.: Human
18 Kinetics; 1997:229-256.
- 19 **55.** Martin K. A. *Puberty, sexuality, and the self: Girls and boys at adolescence*. New
20 York: Routledge; 1996.
- 21 **56.** Cover-Jones M. A study of socialization patterns at the high school level. *Journal*
22 *of Genetic Psychology*. 1958;93:87-111.
- 23 **57.** Cash T. F. *The body-image workbook: An eight step program for learning to like*
24 *your looks*. Oakland, CA: New Harbinger; 1997.
- 25 **58.** Cash T. F., Strachan M. D. Cognitive-behavioral approaches to changing body
26 image. In: Cash TF, Pruzinsky T, eds. *Body image: A handbook of theory,*
27 *research, and clinical practice*. New York, NY: Guilford Press; 2002:478-486.
- 28 **59.** Parker S., Nichter M., Nichter M., et al. Body-image and weight concerns among
29 african-american and white adolescent females - differences that make a
30 difference. *Human Organization*. Sum 1995;54:103-114.
- 31 **60.** Cole T. J. Growth charts for both cross-sectional and longitudinal data. *Statistics*
32 *in Medicine*. Dec 30 1994;13:2477-2492.
- 33 **61.** Baxter-Jones A. D. G., Eisenmann J. C., Sherar L. B. Controlling for maturation
34 in pediatric exercise science. *Pediatric Exercise Science*. Feb 2005;17:18-30.

MATURATION, PHYSICAL SELF, PHYSICAL ACTIVITY

1 Table 1. Descriptive statistics for chronological age, estimated biological maturity status,
2 physical self-perceptions, and physical activity of adolescent British female pupils by age
3 group.

	11years* n=54	12years n=88	13years n=60	14years n=20
Chronological age	11.59 (.2)	12.47 (.3)	13.39 (.3)	14.11 (.1)
Maturity status z-score	-.13 (.87)	-.29 (.92)	.07 (.87)	-.43 (.70)
Height (cm)	151.9 (7.5)	155.0 (6.6)	161.8 (6.2)	163.1 (6.3)
Weight (kg)	43.6 (8.5)	46.7 (8.6)	55.3 (9.6)	54.2 (6.5)
BMI (kg/m ²)	18.8 (2.6)	19.3 (2.8)	21.1 (3.2)	20.3 (1.9)
Sport competence	2.57 (.71)	2.65 (.61)	2.56 (.65)	2.64 (.74)
Physical condition	2.69 (.70)	2.87 (.58)	2.69 (.72)	2.81 (.77)
Body attractiveness	2.54 (.62)	2.54 (.69)	2.37 (.74)	2.47 (.65)
Physical strength	2.58 (.58)	2.58 (.51)	2.55 (.60)	2.38 (.48)
Physical self-worth	2.68 (.70)	2.72 (.67)	2.61 (.68)	2.62 (.73)
Physical activity	2.67 (.64)	2.54 (.56)	2.59 (.69)	2.71 (.66)
Health-related quality of life	47.0 (7.8)	45.5 (7.2)	46.0 (7.3)	44.9 (6.5)
Percentage of predicted adult stature attained	90.9 (2.9)	93.6 (2.7)	97.0 (1.9)	97.7 (.9)

5

6

7 * This subsample includes one child aged 10.93 years

Table 2. Pearson product moment correlations (one-tailed) between measures of estimated biological maturity status, physical self-concept, physical activity, and health-related quality of life.

	1	2	3	4	5	6	7
1. Biological maturity status							
2. Sport competence	-.18**						
3. Physical condition	-.27***	.82***					
4. Body attractiveness	-.34***	.61***	.61***				
5. Physical strength	.10	.55***	.48***	.38***			
6. Physical self-worth	-.25***	.76***	.74***	.83***	.51***		
7. Physical activity	-.18**	.51***	.52***	.33***	.40***	.43***	
8. Health-related quality of life	-.12*	.43***	.38***	.42***	.26***	.52***	.21**

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

Figure 1. Hypothesized mediated effects model describing relations among biological maturity status, physical self-concept, physical activity and health-related quality of life in adolescent females.

Figure 2. Mediated effects model describing relations among biological maturity status, physical self-concept, physical activity and health related quality of life in adolescent females.

Note. All solid line parameters are significant ($p < .05$). Dashed line parameters are non-significant. Standardized Beta coefficients are presented by each parameter with standard errors in parentheses. Indirect effects were observed between maturity status and physical self-worth ($\beta = -.28$ (BBC 90% CI = $-.39, -.17$), $P < .001$), maturity status and physical activity ($\beta = -.14$ (BBC 90% CI = $-.22, -.08$), $P < .001$), and maturity status and health related quality of life ($\beta = -.17$ (BBC 90% CI = $-.25, -.10$), $P < .001$). Factors indicators are not included in the model for the purpose of making the presentation less complex. Correlations between the errors associated with the four sub-dimensions of the physical self were all significant and were as follows; sport competence & physical condition $r = .92$; sport competence & body attractiveness $r = .67$; sport competence & strength $r = .66$; physical condition & body attractiveness $r = .63$; physical condition & strength $r = .60$; body attractiveness & strength $r = .49$.