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Longitudinal association of biological maturation with physical activity behaviors in girls transitioning from 5th to 7th grade

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Abstract

Introduction: This longitudinal study determined if social cognitive variables influence physical activity in girls stratified on the basis of maturity status.

Methods: Participants attended South Carolina public schools (Mage in 5th grade = 11.1 years) and included a cohort of 529 girls who provided physical activity data in the 5th grade and in 6th and/or 7th grade. The measure of maturity status was age at peak height velocity (APHV) estimated from maturity offset when the children were in the 5th grade. The Earlier Maturity (EM) group included girls whose APHV was one standard deviation or more below the mean APHV for the full sample. All other girls were placed in the Later Maturity (LM) group. Physical activity was assessed at each time point via accelerometry. Social-cognitive variables were assessed at each time point by a questionnaire measuring self-efficacy, enjoyment, competence, appearance, fitness, and social motives for physical activity. Growth curves for the total, Earlier Maturing, and Later Maturing groups assessed relationships between physical activity over time and time-varying social cognitive variables.

Results: Physical activity was lower in the Earlier Maturing group and was positively associated with self-efficacy and enjoyment motivation in the total group. These relationships were observed in the 5th grade and maintained through 7th grade. In the Later Maturing group, we observed positive relationships between physical activity and self-efficacy, enjoyment and competence motivation.

Conclusions: Strategies to increase confidence, skills, and enjoyment of physical activity may only be effective for promoting activity among later maturing girls.

1 | INTRODUCTION

Physical activity provides important health benefits to children and adolescents (Poitras et al., 2016), and both the U.S. Department of Health and Human Services (U.S. Department of Health and Human Services, 2018) and the World Health Organization (Bull et al., 2020) have established physical activity guidelines for school-aged

youth. Both of those authorities have recommended that youth engage in at least 60 min of moderate-to-vigorous intensity physical activity per day, but it is well documented that most young people over the age of 11 years do not meet that standard (National Physical Activity Plan Alliance, 2018). It is also clear that the prevalence of meeting physical activity guidelines is considerably lower in girls than boys, and recent surveys in the United States have shown that only 15% of girls in grades 9–12 are physically active at the recommended level, compared to 31% of boys (Merlo et al., 2020).

The gender difference in physical activity has been studied extensively in youth, and multiple factors have been suggested as potential explanations for the lower activity levels observed in girls (Miller et al., 2018). These include physiological, social-cognitive, social environmental, and cultural influences on physical activity behavior (Spencer et al., 2015). Because girls typically achieve biological maturity at a younger chronological age than boys, particular attention has been given to the influence of maturation on physical activity behavior in youth (Biro et al., 2001; Cairney et al., 2014; Cumming et al., 2014; Lee, 1980). In studies focusing only on girls, some have observed that girls who mature early engage in physical activity at lower levels (Cumming et al., 2008; Davison et al., 2007; Thompson et al., 2003); however, other studies have reported no association between maturity and physical activity (Drenowatz et al., 2010; Sherar et al., 2009; Wickel et al., 2009). Two studies have found higher physical activity in early maturing girls (Fawkner et al., 2014; van Jaarsveld et al., 2007). These inconsistencies may be explained, in part, by differences in study designs (e.g., cross-sectional vs. longitudinal), measures of maturity, and measures of physical activity (e.g., self-report vs. device-based) (Cairney et al., 2014; Cumming et al., 2008, 2014; Malina, 2014; Thompson et al., 2003).

Developmental changes in physical activity also have been linked to social-cognitive factors, including beliefs about barriers to physical activity, self-efficacy for overcoming these barriers, and enjoyment, fitness, appearance, and social goals (Dishman et al., 2017; Dishman et al., 2019). While both maturity and social-cognitive factors have been observed to be associated with physical activity in girls (Dishman et al., 2009; Dishman et al., 2010; Dowda et al., 2007; Dowda et al., 2009), the relationship between the two characteristics has not been studied extensively. Specifically, it is not known how maturity influences the relationships between social-cognitive variables and physical activity in girls. Accordingly, the purposes of this study were: (1) to compare device-measured physical activity between girls who matured earlier and those who matured later as they transitioned from 5th to 7th grade; (2) to compare self-efficacy and motives for physical activity in girls who matured earlier versus later; and (3) to determine if social-cognitive variables influence physical activity in girls stratified on the basis of maturity status.

2 | METHODS

2.1 | Participants and study design

Participants were enrolled in the Transitions and Activity Changes in Kids (TRACK) study, a multilevel, longitudinal study of influences on the changes in physical activity that occur as children transition from elementary to middle school. Children were recruited from 21 public elementary schools in two school districts in South Carolina. Children in 5th grade were invited to participate in the study, which included annual follow-up through 7th grade. All data on a given child at each time point were collected within a narrow window, ordinarily within 1 week. Written informed consent and assent were obtained from the primary guardian and each child before beginning study procedures. The study was approved by the Institutional Review Board at the University of South Carolina. For this analysis, the sample was limited to girls with baseline data for physical activity in 5th grade as well as ≥1 other time point, resulting in a cohort of 529 girls.

2.2 | Measures

2.2.1 | Demographic characteristics

Race/ethnicity and age were self-reported in 5th grade. Girls reported whether they identified as White, Black/African American, Asian, American Indian/Alaskan Native, or Other, as well as whether they considered themselves Hispanic or Latino. Responses to race/ethnicity questions were coded as non-Hispanic Black, non-Hispanic white, Hispanic, and other/mixed race. Parents reported their highest level of education, which served as a proxy measure of socioeconomic status. Chronological age was determined using the student's birthday and the measurement date.

2.2.2 | Anthropometric measures

Participants' height, seated height, and weight were measured in 5th grade. Girls were asked to remove heavy clothing and shoes, and the average of two measurements was used for all three measures. Trained staff measured

standing and seated heights with a portable stadiometer (Seca, Hamburg, Germany) and weight using an electronic scale (Model 770; Seca). Body mass index (BMI) was calculated using the equation kg/m^2. Ten data collectors were employed over the course of the study. Data collectors were trained to perform a standardized data collection protocol based on the National Health and Nutrition Examination Survey (NHANES) anthropometry procedures manual. Data collectors were certified by a senior staff member before being released into the field. To be certified, each data collector was required to be within 0.5 cm of the senior staff member's measures on height and circumferences, and 0.5 kg on weight. Booster training and recertification was completed every 6 months. In the field, reliability was assessed every 6 months. All height and weight measures were taken in duplicate. If two measures were more than 0.5 cm or 0.5 kg different, additional measures were taken until reliable measures were achieved. Circumferences were taken in triplicate, and any value more than 0.5 cm different was taken again, until reliable measures were achieved.

2.2.3 | Maturity

The measure of maturity status was age at peak height velocity (APHV) estimated from maturity offset when the children were in the 5th grade. Maturity offset is the difference, expressed in years, between the child's chronological age and his/her estimated APHV. APHV is the age at which a child experiences his/her most rapid increase in stature. Maturity offset was estimated from measures of height and seated height using the longitudinally validated prediction of equation of Mirwald et al. (Mirwald et al., 2002). APHV was then calculated from chronological age and maturity offset (APHV = chronological age – maturity offset). For this study, two maturity groups were created. The Earlier Maturity (EM) group included girls whose APHV was one standard deviation or more below the mean APHV for the full sample. All other girls were placed in the Later Maturity (LM) group. In the total sample of girls included in this study mean APHV was 11.6 + 0.54 years (X + SD). Accordingly, the EM group included girls whose APHV was 11.04 years or less. Mean APHV was 10.76 + 0.24 years for the EM group and 11.76 + 0.44 years for the LM group.

2.2.4 | Physical activity

Physical activity was measured using ActiGraph accelerometers (models GT1M, GT3X, and GT3X+). The ActiGraph has been validated for use with children, and Actigraph data correlate strongly with energy expenditure. (Treuth et al., 2004) Children were asked to wear the accelerometer over their right hip for seven consecutive days during waking hours. They were instructed to remove the accelerometer when showering, engaging in other water activities, or sleeping. Monitors were initialized prior to data collection and were set to begin collecting data on the day after they were distributed to participants at their schools. Accelerometer data were collected and stored in 60-s epochs. Any period of 60 minutes or more with consecutive zeros was considered non-wear time, and data collected on Sundays were excluded from the analysis due to low reliability. A threshold of 100 counts per minute was used to distinguish sedentary behavior from total physical activity, which includes activities in the light, moderate, and vigorous intensity categories, corresponding to ≥2.0 metabolic equivalents (METs). Physical activity was expressed as mean daily minutes per hour of accelerometer wear time.

2.2.5 | Social-cognitive variables

Social-cognitive variables were assessed by a questionnaire administered to participants during the school day by trained data collectors. Self-efficacy for overcoming barriers to physical activity was assessed by eight items. Each item on the self-efficacy scale (Cronbach alpha = .79) is a simple declarative statement to which participants responded using a 4-point scale, ranging from 1 (disagree a lot) to 4 (agree a lot). The self-efficacy variable is operationally defined as the mean of scores on the eight items. In a previous study, model fit was good for both overweight and normal weight girls in 5th and 6th grades (Dishman et al., 2013).

The Motivation for Physical Activity Measure-Revised (MPAM-R) assessed motives for physical activity. Five scales were employed to measure extrinsic and intrinsic motives for physical activity: (1) enjoyment, (2) competence, (3) appearance, (4) fitness, and (5) social motives. Each item is a simple declarative statement to which participants respond using a 4-point scale, ranging from 1 (not true at all for me) to 4 (very true for me). The enjoyment (Cronbach alpha = .76), competence (Cronbach alpha = .74), appearance (Cronbach alpha = .85), and fitness (Cronbach alpha = .69) scales are operationally defined as the mean of scores on four items, while the social (Cronbach alpha = .62) scale is operationally defined as the mean of scores on three items. In a previous study, factor validity was acceptable for both overweight and normal weight girls in the 5th and 6th grade (Dishman et al., 2013).

2.3 | Statistical analysis

Descriptive statistics for the girls were calculated for the total group and by maturity group using t-tests and Chi-square analyses in SAS (Version 9.4; Cary, NC). A growth curve analysis (PROC MIXED) was used to determine if there were differences in physical activity over time by maturity group. These analyses were conducted with and without adjustment for race/ethnicity and 5th grade BMI. Means (SD) were calculated for self-efficacy and the five motivation variables by grade and by maturity group. A two-way repeated measures analysis examined the effects of group, time, and interaction between group and time, adjusting for BMI and race.

To determine if the social-cognitive variables influenced physical activity, separate growth curves for the total, Earlier Maturing, and Later Maturing groups were evaluated using the PROC MIXED procedure. Time-varying self-efficacy and time-varying motivation variables (enjoyment, social, appearance, fitness, and competence) were examined in separate models. Models for the total group included group, time, group by time interaction, and one of the social-cognitive variables (e.g., enjoyment motivation) and interaction of time by the social-cognitive variable (e.g., time by enjoyment motivation). For the maturation group analyses, models included one of the social-cognitive variables and the social-cognitive by time interaction. All models were adjusted for baseline BMI and race. Intercept and time were modeled as random variables and time was coded as 0, 1, or 2. *p*-values less than .05 were considered significant. Analyses that adjusted for baseline BMI were repeated without BMI included in the model to assess whether BMI confounded the results.

3 | RESULTS

3.1 | Descriptive characteristics

A total of 537 girls were originally enrolled in the study. Participants missing data on maturity in the 5th grade were removed ($n = 8$), resulting in a final sample of 529 girls in the 5th grade. Table 1 presents descriptive statistics for parent education, race, chronological age, BMI, and physical activity at each grade. In 5th grade, the sample was about 32.7% African American, 39.4% White, 10.3% Hispanic and 17.7% other, with a mean age of 11.1 years and with 44.9% of parents reporting a high school education or higher. The Earlier Maturing group included a greater percentage of African American girls, and BMI was higher in the Earlier Maturing group compared to the Later Maturing group. In addition, significant differences were observed between the Earlier Maturing and Later Maturing groups for physical activity, which was lower in the Earlier Maturing group at each grade level.

3.2 | Physical activity in earlier maturing versus later maturing girls

Table 2 and Figure 1 present the results of the growth curve analysis for PA. Initial PA was 27.2 min per hour, and there was a decline of −3.16 min/h each year. The groups were significantly different both in the unadjusted model and in the model adjusted for race/ethnicity and BMI. Girls who matured earlier had lower total PA than girls who matured later at each grade level.

3.3 | Comparing self-efficacy and motives for physical activity in earlier maturing versus later maturing girls

Table 3 presents comparisons of the Earlier Maturing and Later Maturing groups on scores for social-cognitive variables by grade, adjusted for race and BMI. There was a significant decline over time in both groups for self-efficacy, enjoyment motivation, competence motivation, and fitness motivation, but not in appearance or social motivation. The groups differed on only one variable, self-efficacy for overcoming barriers to physical activity, with earlier maturing girls scoring higher. Analyses that did not include baseline BMI in the model found that self-efficacy was not different between the groups, but did find that appearance motivation was significantly different between the Earlier and Later Maturing groups.

3.4 | Longitudinal associations between self-efficacy, motives, and total physical activity in earlier maturing and later maturing girls

The growth curves in Table 4 provide the coefficients (SE) for the relationships between the change in total physical activity and the social-cognitive variables. Maturity group was significantly related to total physical activity regardless of the social-cognitive variable in the model, with lower total physical activity in the Earlier Maturing group. We observed significant positive relationships with total physical activity and self-efficacy and enjoyment motivation in the total group. After stratification by maturity group, there were significant positive relationships ($p < .05$) between total physical activity and

TABLE 1 Characteristics of girls at each grade level, by maturity groups

Characteristic	5th grade				6th grade				7th grade			
	Total group ($N = 529$)	Earlier maturing ($n = 87$)	Later maturing ($n = 442$)	*p*-value	Total group ($N = 480$)	Earlier maturing ($n = 79$)	Later maturing ($n = 401$)	*p*-value	Total group ($N = 452$)	Earlier maturing ($n = 78$)	Later maturing ($n = 374$)	*p*-value
Parent education												
≥High School	44.9%	49.4%	44.0%	.36								
<High School	55.1%	50.6%	56.0%									
Race												
White	39.4%	27.6%	41.7%	.01								
African American/ Black	32.7%	44.8%	30.3%									
Hispanic	10.3%	5.8%	11.2%									
Other	17.7%	21.8%	16.9%									
APHV (5th grade)	11.60 (0.56)	10.76 (0.24)	11.76 (0.44)	<.001								
Maturity offset (5th grade)	−0.54 (0.69)	0.21 (0.50)	−0.69 (0.62)	<.001								
Weight	48.17 (13.85)	66.88 (14.01)	44.49 (10.43)	<.001	53.06 (14.80)	72.46 (14.53)	49.24 (11.49)	<.001	58.39 (16.03)	79.11 (16.22)	54.07 (12.16)	<.001
Height	148.62 (7.99)	157.93 (5.60)	146.78 (7.06)	<.001	153.50 (7.45)	162.11 (4.81)	151.80 (6.67)	<.001	157.71 (6.96)	164.50 (5.01)	156.30 (6.46)	<.001
Sitting height	77.42 (4.41)	82.48 (3.51)	76.42 (3.84)	<.001	79.78 (4.14)	84.53 (3.16)	78.85 (3.63)	<.001	82.15 (3.85)	85.79 (3.16)	81.39 (3.54)	<.001
BMI (kg/m^2)	21.56 (5.04)	26.93 (5.92)	20.53 (4.10)	<.001	22.34 (5.34)	27.72 (6.02)	21.29 (4.51)	<.001	23.35 (5.72)	29.36 (6.36)	22.09 (4.70)	<.001
Chronological age (years)	11.06 (0.49)	10.97 (0.44)	11.07 (0.50)	.07	11.98 (0.49)[a]	11.88 (0.41)[c]	12.00 (0.50)[e]	.05	12.97 (0.49)[g]	12.89 (0.43)[i]	12.99 (0.49)[k]	.11
Total PA (mean and SD)	27.24 (4.26)	25.76 (3.96)	27.53 (4.26)	.0004	22.94 (4.42)[b]	21.41 (3.82)[d]	23.23 (4.47)[f]	.002	21.36 (4.36)[h]	20.80 (4.19)[j]	21.47 (4.39)[l]	.28

Abbreviations: APHV, age at peak height velocity; BMI, body mass index; PA, physical activity.
[a] $n = 486$.
[b] $n = 409$.
[c] $n = 80$.
[d] $n = 65$.
[e] $n = 406$.
[f] $n = 344$.
[g] $n = 454$.
[h] $n = 366$.
[i] $n = 76$.
[j] $n = 59$.
[k] $n = 378$.
[l] $n = 307$.

self-efficacy, enjoyment, and competence for the later maturing girls. However, no social-cognitive variables were associated with physical activity in the earlier maturing girls. Results were not different in growth models that did not adjust for baseline BMI.

4 | DISCUSSION

The novel finding in this longitudinal study was that physical activity self-efficacy, competence motivation, and enjoyment motivation were associated with total physical activity in girls who matured later, but that no social-cognitive variables were associated with physical activity in girls who matured earlier. These differences were observed initially in the 5th grade and were maintained throughout the study period. These findings were based on application of growth curve analysis to longitudinal data for a device-based measure of physical activity and selected social-cognitive variables. Growth curve analysis allows for examination of longitudinal associations between time-varying dependent and independent variables. In the present study, both physical activity, the dependent variable, and the social-cognitive variables, the independent variables, were time-varying. The present study is the first to assess the relationship between physical activity and physical activity-specific social-cognitive variables separately in girls based on maturity status. The findings suggest that physical activity-specific social-cognitive variables, several of which were found to be associated with physical activity in later maturing girls, may not influence physical activity in earlier maturing girls.

For girls who mature later, these results suggest that providing enjoyable physical activity opportunities to enhance skills and self-confidence, especially in fun, social settings, remains a primary strategy for promoting physical activity. This is consistent with current quantitative research on physical activity determinants (Dishman et al., 2017; Dishman et al., 2019), as well as a review of qualitative studies that examined adolescent perspectives on influences on their physical activity (Martins et al., 2021). The results also suggest that different physical activity promotion strategies are needed for girls who mature earlier. Previous work suggests that puberty may affect physical activity in girls through variables not assessed in this study—specifically, psychological responses to body changes associated with maturation, such as self-worth, maturity fears, and physical self-concept (Cumming et al., 2012; Davison et al., 2007; Smart et al., 2012). Girls may be more socially self-conscious during puberty (Martins et al., 2021), and therefore more influenced by peer reactions to their maturing bodies. For example, Pindus et al. (2014) found that girls who matured early and on time and also had high-peer acceptance reported greater involvement in physical activity compared to those with lower peer acceptance (Pindus et al., 2014); this relationship did not hold for girls who matured later. Therefore, for earlier maturing girls, strategies to increase their feelings of

TABLE 2 Growth curve model for physical activity ($N = 529$)

	Unadjusted model coefficient (SE)	Adjusted model[a] coefficient (SE)
Intercept	27.2*** (0.20)	28.8 *** (0.78)
Time	−3.16*** (0.12)	−3.16*** (0.12)
Group, earlier maturing	−1.88** (0.49)	−1.38* (0.54)
Group*time	0.41 (0.30)	0.41 (0.30)

[a]Adjusted for race/ethnicity and 5th grade BMI.
*$p < .05$; **$p < .01$; ***$p < .001$.

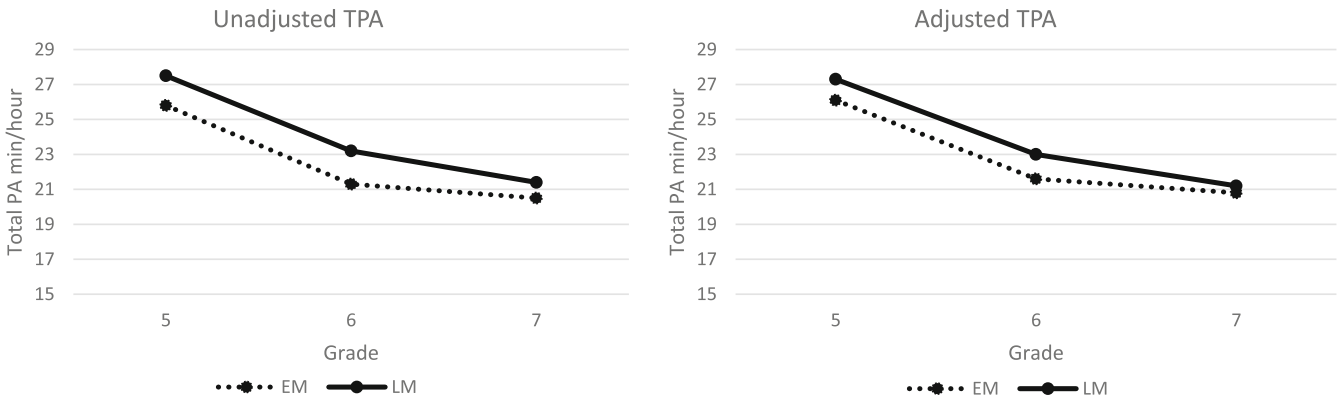

FIGURE 1 Physical activity by grade for earlier and later maturing girls

TABLE 3 Results of two-way repeated measures analysis for social-cognitive variables by maturation group and grade, adjusting for race and 5th grade BMI

Self-efficacy	*n*	Total group	*n*	Earlier maturing	*n*	Later maturing	Group	Time	G*T
5th grade	528	3.3 (0.03)	87	3.31 (0.06)	441	3.20 (0.03)	0.04	0.01	0.97
6th grade	482	3.2 (0.04)	80	3.25 (0.06)	402	3.14 (0.03)			
7th grade	456	3.1 (0.04)	78	3.20 (0.07)	378	3.07 (0.03)			
Enjoyment motivation									
5th grade	529	3.58 (0.04)	87	3.62 (0.07)	442	3.54 (0.03)	0.14	0.03	0.27
6th grade	482	3.52 (0.04)	80	3.54 (0.07)	402	3.50 (0.03)			
7th grade	456	3.48 (0.04)	78	3.56 (0.07)	378	3.39 (0.03)			
Competence motivation									
5th grade	528	3.43 (0.04)	87	3.47 (0.07)	441	3.39 (0.03)	0.07	0.01	0.69
6th grade	482	3.41 (0.04)	80	3.49 (0.08)	402	3.33 (0.03)			
7th grade	456	3.31 (0.04)	87	3.37 (0.08)	378	3.25 (0.03)			
Appearance motivation									
5th grade	529	2.98 (0.05)	87	2.96 (0.09)	442	3.00 (0.04)	0.75	0.38	0.93
6th grade	482	2.99 (0.05)	80	2.99 (0.09)	402	2.99 (0.04)			
7th grade	456	2.92 (0.05)	78	2.91 (0.10)	378	2.94 (0.04)			
Fitness motivation									
5th grade	529	3.70 (0.03)	87	3.71 (0.06)	442	3.68 (0.03)	0.60	<0.001	0.89
6th grade	482	3.62 (0.03)	80	3.64 (0.06)	402	3.60 (0.03)			
7th grade	456	3.53 (0.03)	78	3.54 (0.06)	378	3.53 (0.03)			
Social motivation									
5th grade	529	3.03 (0.05)	87	3.05 (0.09)	442	3.01 (0.04)	0.25	0.17	0.36
6th grade	482	3.12 (0.05)	80	3.20 (0.09)	402	3.03 (0.04)			
7th grade	456	3.03 (0.05)	78	3.06 (0.09)	378	3.00 (0.04)			

positive self-worth and reduce feelings of self-consciousness due to their changing bodies (Davison et al., 2007) may be beneficial for promoting physical activity. Furthermore, the biocultural model of maturity (Cumming et al., 2012) posits that additional, broader sociocultural factors, such as changing social norms and sociocultural factors, may also influence participation in physical activity as girls move through puberty. For example, in a review of qualitative studies that examined adolescent perspectives on influences on their physical activity, girls reported that expectations of gender-appropriate behavior (e.g., "physical activity is not feminine") also affected participation in physical activity (Martins et al., 2021).

Interestingly, earlier maturing girls in this study had significantly higher physical activity self-efficacy scores compared to later maturing girls. This was unexpected, but as noted above, the physical activity-specific social-cognitive variables were not associated with total physical activity in earlier maturing girls. This study also showed that girls in the Earlier Maturing compared to Later Maturing group participated in lower levels of physical activity, measured by accelerometry, though both groups declined over time. This finding is consistent with other studies which found that the age-related decline in physical activity in children and youth is aligned more closely with biological age than with chronological age (Cairney et al., 2014; Cumming et al., 2008; Sherar et al., 2007; Thompson et al., 2003). Future research should consider psychological and social responses to girls' maturing bodies (e.g., self-worth, maturity fears, physical self-concept, peer acceptance) in addition to specific social-cognitive influences (e.g., physical activity self-efficacy), as well as explore the role of gender-based sociocultural norms. Based on this work, physical activity promotion for girls should be designed to make physical activity personally, socially, and normatively relevant for girls as they mature. For example, school-based physical education programs may be more effective for maturing girls if delivered in a gender-separate environment (Davison et al., 2007; Pate et al., 2005). Future work also should measure the association between physical activity and

TABLE 4 Growth curves for total, earlier and later maturing groups, adjusting for baseline BMI and race

	Total group	Earlier maturing	Later maturing
Self efficacy			
Intercept	22.41*** (1.81)	25.44*** (2.90)	25.23*** (1.41)
Time	−2.06* (0.92)	−4.05* (1.88)	−2.61*** (0.76)
Group, earlier maturing	−1.49* (0.53)		
Time*group	−0.41 (0.30)		
Self-efficacy	0.94** (0.28)	−0.19 (0.73)	1.11*** (0.30)
Time*self-efficacy	−0.07 (0.22)	0.43 (0.58)	−0.16 (0.24)
Enjoyment			
Intercept	26.09*** (1.32)	26.33*** (3.0)	25.85*** (1.49)
Time	−2.22*** (0.71)	−5.22** (1.82)	−1.64* (0.77)
Group, earlier maturing	−1.40* (0.53)		
Time*group	−0.39 (0.30)		
Enjoy	0.72* (0.01)	−0.44 (0.69)	0.93** (0.31)
Time*enjoy	−0.26 (0.20)	0.72 (0.51)	−0.43† (0.22)
Social			
Intercept	25.09*** (1.62)	25.35*** (2.02)	28.17*** (1.14)
Time	−1.90* (0.74)	−3.05* (1.30)	−2.60*** (0.53)
Group, earlier maturing	−1.38** (0.53)		
Time*group	−0.40 (0.30)		
Social	0.34 (0.20)	−0.21 (0.48)	0.41 (0.22)†
Time*social	−0.15 (0.16)	0.12 (0.42)	−0.19 (0.17)
Appearance			
Intercept	29.3*** (0.90)	26.1*** (2.07)	29.87*** (1.05)
Time	−3.41*** (0.44)	−3.51* (1.26)	−3.37*** (0.47)
Group, earlier maturing	−1.36* (0.54)		
Time*group	0.38 (0.30)		

TABLE 4 (Continued)

	Total group	Earlier maturing	Later maturing
Appear	−0.24 (0.20)	−0.53 (0.55)	−0.24 (0.21)
Time*appear	0.08 (0.14)	0.25 (0.39)	0.07 (0.16)
Fitness			
Intercept	27.35*** (1.40)	29.14*** (3.78)	27.28*** (1.54)
Time	−3.17*** (0.89)	−6.32* (2.41)	−2.67* (0.96)
Group, earlier maturing	−1.40* (0.54)		
Time*Group	0.41 (0.30)		
Fitness	0.40 (0.32)	−1.18 (0.94)	0.57† (0.33)
Time*fitness	0.01 (0.24)	0.99 (0.66)	−0.13 (0.26)
Competence			
Intercept	27.34*** (1.19)	26.16*** (2.81)	27.32*** (1.33)
Time	−2.54*** (0.65)	−5.22** (1.59)	−1.95* (0.71)
Group, earlier maturing	−1.40* (0.54)		
Time*group	0.41 (0.30)		
Competence	0.42 (0.26)	−0.42 (0.63)	0.60* (0.28)
Time*competence	−0.18 (0.19)	0.76 (0.46)	−0.36† (0.21)

*$p < .05$; **$p < .01$; ***$p < .001$; †$p < 10$.

social-cognitive variables prior to 5th grade, before the onset of maturity, to better examine the relationship between maturity, physical activity, and social-cognitive variables.

The earlier compared to later maturing girls in this study had significantly higher BMI at baseline. This is consistent with previous reports that an increase in fat mass and subsequent increase in BMI is associated with biological maturation (Biro et al., 2001; Cumming et al., 2014). Because BMI is inversely associated with physical activity (Janssen et al., 2019), in this study we opted to control for baseline BMI in analyses. Future work should further examine the complex relationships among BMI, maturity status, social-cognitive influences, and physcial activity (Jago et al., 2020). Analyses were replicated without adusting for baseline BMI. This did not affect the results of the growth curve analyses, but it did influence the results of repeated measures analyses. This supports the need to adjust for baseline BMI in order to conclude that the results of the analyses are independent of BMI status.

The present study was undertaken in a sample of girls that was very diverse in race/ethnicity. This diversity represents a methodological challenge, as the use of APHV as the measure of maturity has not been validated among females of non-European ancestry. As can be seen in Table 1, race/ethnicity was not uniformly distributed across maturity groups. Table 5 provides detail on the racial/ethnic differences in height, seated height, weight, BMI, and maturity status. The use of APHV as the measure of maturity may not be equally appropriate for every race/ethnicity subgroup, and it may further be limited by

TABLE 5 Comparison of anthropometric variables across race/ethnicity groups in the 5th grade, presented as least square means and standard errors from regression models ($N = 526$)

	Black $n = 172$	Hispanic $n = 54$	Other $n = 93$	White $n = 207$	p-value
Height[a]	54.95	43.76	48.09	45.59	<.0001
Weight[b]	52.95	43.76	48.09	45.59	<.0001
Seated height	77.41	76.4	77.87	77.52	.26
Age	11.07	10.9	11.13	11.06	.06
BMI[b]	23.09	20.29	21.37	20.85	<.0001
Maturity[c]	−0.38	−0.80	−0.49	−0.62	<.0001

[a]Significant differences ($p < .05$) between Black and Hispanic girls and Black and White girls.
[b]Significant differences ($p < .05$) between Black and Hispanic girls, Black and White girls, and Black and other girls.
[c]Significant differences ($p < .05$) between Black and Hispanic girls, Black and White girls, and Hispanic and other girls.

the potential overestimation of the timing of PHV associated with equation-based methods (Mills et al., 2017). Nonetheless, equation-based methods for predicting PHV in adolescents are the most accessible for use in large cohort studies (Mills et al., 2017). Future research on physical activity in racially diverse groups should consider selecting measures of maturity that are well validated in the race/ethnicity groups to which they are applied.

Major strengths of the current study include the longitudinal design with a large sample size, an objective measure of physical activity, and an examination of time-varying changes in physical activity and potential social-cognitive influences on physical activity. This study is not without its limitations. The observational design did not allow for causal inferences to be made based upon the findings. Also, because group differences were present in the 5th grade, we could not discern the temporality of the relationship between social-cognitive variables, maturation, and physical activity. The sample size of the Earlier Maturing group was relatively small, which may have limited statistical power. We assessed key physical activity-specific social-cognitive factors but did not assess other psychological responses to body maturation. Additionally, we selected the Mirwald et al. (Mirwald et al., 2002) method for assessing maturity and used a method similar to that of Drenowatz et al. (Drenowatz et al., 2010) to create maturity groups. The use of an alternative method for assessing maturity could potentially influence these findings. Finally, all participants in this study were adolescent girls going to school in South Carolina, limiting generalizability.

5 | CONCLUSIONS

Social-cognitive influences on physical activity from grades 5 to 7 varied by maturation status. Self-efficacy, competence motivation, and enjoyment motivation were associated with physical activity in later maturing girls. This suggests that strategies to increase confidence, skills, and enjoyment of physical activity may be effective with this group. However, no physical activity-specific social-cognitive variables were associated with physical activity in earlier maturing girls. This suggests that factors not assessed in this study should be considered and physical activity opportunities designed accordingly, as girls move through puberty. These include psychological influences related to maturation (e.g., self-consciousness, physical self-concept, global self-worth) and social and socio-cultural influences (e.g., peer acceptance, normative gender expectations). The goal is to provide physical activity opportunities that are personally and socially relevant to girls as they mature, thereby reducing declines in girls' physical activity.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Russell Pate: Conceptualization (lead); methodology (equal); supervision (lead); writing – original draft (equal); writing – review and editing (equal). **Marsha Dowda:** Data curation (lead); formal analysis (equal); methodology (equal); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Rod K. Dishman:** Formal analysis (equal); methodology (equal); validation (equal); writing – original draft (equal); writing – review and editing

(equal). **Joseph Gorab:** Conceptualization (equal); methodology (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Agnes Bucko:** Visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Ruth P. Saunders:** Conceptualization (equal); methodology (equal); writing – original draft (equal); writing – review and editing (equal).

DATA AVAILABILITY STATEMENT

Author elects to not share data.

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