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Pubertal Timing and Tempo: Associations With Childhood Maltreatment

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Abstract

The present study examined pubertal timing and tempo in a sample of 445 adolescents (53% male), using both variable-centered (latent growth curve) and person-centered (latent class) approaches, to discern the pubertal development trajectories associated with the experience of maltreatment. Results from the variable-centered analyses indicated a slower initial tempo that increased later for boys who had experienced neglect. The person-centered results indicated three classes for boys that mainly differentiated tempo effects and two classes for girls primarily distinguishing timing differences. For girls, sexual abuse predicted membership in an earlier pubertal timing class. These findings enhance our knowledge of the variability in pubertal development as well as gender differences in maltreatment types that may alter pubertal timing and tempo.

Keywords

pubertal timing; pubertal tempo; maltreatment

For more than 50 years, researchers have recognized the timing of pubertal development as an important and unique risk factor for numerous health and behavior problems. Studies have implicated that early timing, in particular, serves as a risk for depression, eating disorders, substance use, sexual activity, and delinquency (Cavanagh, 2004; Ge, Conger, & Elder, 2001; Negriff & Trickett, 2010; Stice, Presnell, & Bearman, 2001). The challenge with examining pubertal timing across development is that tempo (speed of pubertal development) is variable. For example, an adolescent who exhibits *early* pubertal development at the first assessment may progress at a slow tempo and be *on-time* at the next assessment, essentially allowing the on-time developers to *catch-up*. Despite the accumulation of evidence that early pubertal timing in adolescence has both acute and persistent effects on adjustment and functioning (Graber, Seeley, Brooks-Gunn, &

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Lewinsohn, 2004), there is less evidence comparing the effects of slower versus faster progression through puberty and whether one may be more detrimental than the other.

Pubertal Timing and Tempo

Investigations into the association between pubertal timing and tempo are in their infancy, with the first studies conducted only within the past 15 years (e.g., Biro et al., 2001; Laitinen-Krispijn, van der Ende, & Verhulst, 1999). It has been argued that timing and tempo may be correlated because of a common endocrine mechanism underlying both (Dorn & Biro, 2011). There is empirical evidence of significant correlations between timing and tempo, although, others have not found this same association. For example, several studies have found an inverse association between timing and tempo in girls; earlier timing of puberty has been found to be correlated with faster tempo (Biro et al., 2001; Mendle, Harden, Brooks-Gunn, & Graber, 2010; Pantiotou et al., 2008). Conversely, there are other studies that show no association between timing and tempo for girls (B. Huang, Biro, & Dorn, 2009) or no association for girls but an inverse relation for boys (Marceau, Ram, Houts, Grimm, & Susman, 2011). One factor that should be noted in these studies is that unless children are measured at a young age and followed for a long time, timing and tempo will likely always be inversely correlated because the most-developed children at study onset have less development to achieve, which limits the measurement of their rate of change.

More recently, the use of nonlinear growth models, piecewise growth models, and latent growth curve models have begun to significantly advance our understanding of pubertal timing and tempo. For example, in a sample of 364 boys and 373 girls, Marceau and colleagues (Marceau et al., 2011) found that earlier timing and faster tempo independently predicted internalizing and externalizing problems for girls but not for boys, whereas an interaction between timing and tempo predicted externalizing problems for boys. Specifically, faster tempo was associated with more externalizing problems only for early developers. A study of 138 girls and 128 boys found that timing was important for girls in predicting depressive symptoms, but tempo was not (Mendle et al., 2010). However, for boys, early timing and faster tempo were significantly related to depressive symptoms, with tempo having more pronounced effects. Similar to the research concerning the correlation between timing and tempo, the research on the outcomes associated with timing versus tempo have produced somewhat mixed results. Nevertheless, the findings of these studies demonstrate that the timing and rate of pubertal development are not synonymous and should be considered individually when examining outcomes as well as predictors of the variability in pubertal development.

Child Maltreatment and Pubertal Development

To date, the extant literature has largely examined outcomes associated with pubertal timing, with most studies finding that early pubertal timing leads to adverse consequences (for a review, see Mendle & Ferrero, 2012; Mendle, Turkheimer, & Emery, 2007; Negriff & Susman, 2011). Although there is a substantial body of research examining the precursors of individual differences in pubertal timing, this area of research lags somewhat behind the

research on outcomes. Examining the predictors of pubertal development is integral for identifying the casual pathways from early life experiences to pubertal development and subsequent maladjustment.

Most of the work regarding the predictors of pubertal timing has implicated early adverse experiences (e.g., father's absence, conflict in the home, and child maltreatment) as harbingers of early puberty (Ellis, 2004; Ellis & Garber, 2000). This work is based on the evolutionary theory of socialization, which asserts that early environment affects the onset and rate of reproductive maturity (Belsky, Steinberg, & Draper, 1991). In an environment with scarce resources, pubertal development and sexual behavior will accelerate to serve the goal of reproduction, with girls being particularly sensitive to these environmental risks (Ellis, 2004). Within this theory, child maltreatment has been discussed as an adverse experience with all the hallmarks of the negative family context and childrearing practices that may hasten pubertal onset. Belsky and colleagues posit that early stress will make an individual more "biologically reactive to social conditions" (Belsky et al., 1991, p. 658), thereby instigating earlier pubertal onset.

However, other researchers have posited that the effects of maltreatment on puberty may be caused by direct alterations in the stress system rather than via social cues (Trickett & Putnam, 1993). Studies have shown that early adversity, including maltreatment, can alter the reactivity of the hypothalamic-pituitary-adrenal (HPA) axis, with chronic stressful experiences resulting in a downregulation of the stress system (Carpenter et al., 2007; Elzinga et al., 2008; Essex et al., 2011; Gordis, Granger, Susman, & Trickett, 2008). The attenuated cortisol profile shown in individuals who have experienced maltreatment may actually hasten the onset of puberty in these individuals because the stress function of the HPA axis is dampened, allowing the cascade of pubertal hormones via the hypothalamic-pituitary-gonadal (HPG) axis to commence. This theory is supported by evidence showing that HPA and HPG coupling in adolescence is modified by early life stress resulting in the inverse coupling patterns seen in adults (Ruttle, Shirtcliff, Armstrong, Klein, & Essex, 2013). The hormonal coupling in adulthood indicates that the HPA and HPG axes are inversely related, with the gonadal hormones being suppressed by the HPA axis and vice versa (Bingaman, Magnuson, Gray, & Handa, 1994; Elias, 1981; Handa et al., 1994). These findings also suggest that pubertal tempo may be accelerated for individuals who have experienced early life stress.

Both theoretical mechanisms described above are supported by a number of studies that find that child maltreatment is associated with early pubertal timing (Costello, Sung, Worthman, & Angold, 2007; Foster, Hagan, & Brooks-Gunn, 2008; Romans, Martin, Gendall, & Herbison, 2003). Many studies have found that sexual abuse, in particular, is a distinct and dominant risk factor for early puberty or early menarche in girls (Brown, Cohen, Chen, Smailes, & Johnson, 2004; Herman-Giddens, Sandler, & Friedman, 1988; Turner, Runtz, & Galambos, 1999; Zabin, Emerson, & Rowland, 2005), although most of these studies lack the design to draw conclusions about the casual sequence between sexual abuse and early puberty.

Unfortunately, there is still a significant gap in knowledge regarding the effects of maltreatment on the pubertal development of boys because most of the research has been conducted with female samples. One study that did include boys in the sample showed that physical abuse and neglect were associated with earlier puberty in boys but not after controlling for sexual abuse (Brown et al., 2004). However, sexual abuse was related to early menarche in girls. These findings demonstrate that different types of maltreatment are, perhaps, salient for the pubertal development of boys versus that of girls. Moreover, although research has examined maltreatment as a predictor of pubertal timing, only one study, to date, has examined maltreatment types in relation to both pubertal timing and tempo. Mendle and colleagues (2011) examined a sample of 100 girls in foster care and found pubertal onset was significantly earlier for those who experienced sexual abuse, but tempo was faster for those who experienced physical abuse. However, a challenge in discerning the effects of specific maltreatment experiences is that there is often high co-occurrence between various maltreatment subtypes. Therefore there are still substantial gaps in knowledge about the effects of maltreatment, and maltreatment subtypes, on pubertal development across adolescence and how these early adverse experiences may differ between boys and girls.

The Present Study

In modeling pubertal trajectories across adolescence, some researchers have taken a variable-centered approach (e.g., Marceau et al., 2011; Mendle et al., 2010), whereas others have taken a person-centered approach (e.g., Cance, Ennett, Morgan-Lopez, & Foshee, 2012). In variable-centered analyses, the focus is on understanding the relation among the variables, with the assumption that all participants are the same (B.O. Muthén & L.K. Muthén, 2000). Variable-centered growth curve analyses provide information on average growth across all individuals. The assumption made is that one developmental function is sufficient in describing the growth for all individuals in a given population (Burchinal & Applebaum, 1991). Using this approach, we can examine the rate of change in pubertal development across adolescents (separately for boys and girls), with the assumption that the identified pattern of change (which can range from no change to higher-order polynomials) is the same for all individuals. The variable-centered approach tells us how individuals, as a group, are in their rate of pubertal development.

In contrast, person-centered analyses allow the examination of group heterogeneity (B.O. Muthén & L.K. Muthén, 2000). These analyses permit tests of whether there are individual differences in the rate of growth and change, or in other words, whether there are prototypic growth curves (Burchinal & Applebaum, 1991). By conducting person-centered analyses, we can determine whether there are groups of children who follow different pubertal development patterns, with no assumptions made regarding the particular patterns of change for the groups. Predictors then allow us to determine factors that can serve to distinguish between the different developmental patterns, and in that sense, explain why some children may change at one rate versus a different rate.

In the present study, we use both approaches to address two aims: 1) to determine the trajectory of pubertal development across adolescence and (2) to examine maltreatment type

as a predictor of pubertal growth trajectories. Regarding the first aim, using the variable-centered analyses we identified the average pubertal trajectory across adolescence. Using the person-centered analyses, we determined whether there are distinct groups of adolescents who follow different pubertal timing and tempo trajectories across adolescence. Regarding the second aim, maltreatment type was examined as a predictor of the average pubertal growth trajectory using the variable-centered approach whereas maltreatment type predicted pubertal trajectory groups (or classes) using the person-centered approach. Based on the existing literature and theory, it was expected that maltreatment, particularly sexual abuse for girls, would predict earlier pubertal timing. However, predictions regarding the associations between maltreatment and pubertal tempo could not be conceived because of the small amount of extant evidence on which to base expectations. The method in the present research of using both the variable-centered and person-centered analytical approaches is in line with recent opinions that these two approaches complement each other and lead to more complete understandings of developmental processes (Laursen & Hoff, 2006; B.O. Muthén & L.K. Muthén, 2000).

Method

Participants

Data were obtained from the first three assessments (approximately 1 year apart) of an ongoing longitudinal study examining the effects of maltreatment on adolescent development. At Time 1, the sample was composed of 454 adolescents (241 males) aged 8–13 years. Participants ranged from age 10 to 16 years at Time 2 and from 11 to 18 years at Time 3. For the present study, adolescents with missing data at all three time points on the pubertal measure of interest were excluded from analyses ($n=9$).

Recruitment

The participants who comprised the maltreatment group ($n=303$) were recruited from active cases in the Department of Children and Family Services (DCFS) of a large west coast city. The inclusion criteria were: (1) a new substantiated referral to DCFS in the preceding month for any type of maltreatment (i.e., neglect, physical abuse, sexual abuse, or emotional abuse), (2) age of 9–12 years, (3) identified as Latino, African-American, or Caucasian (non-Latino), and (4) residing in one of 10 zip codes in a designated county at the time of referral to DCFS. With the approval of DCFS and the institutional review board of the affiliated university, caretakers of potential participants were contacted via postcard and asked to indicate their willingness to participate. Contact via mail was followed up with a phone call.

According to the information abstracted from the DCFS case records, most children in the maltreatment group experienced multiple forms of maltreatment and had multiple referrals, as well. The majority (76.6%) of the maltreatment sample experienced neglect in some form, 51.5% experienced physical abuse, emotional abuse, or both, and 19.8% experienced sexual abuse. On average, the participants had experienced two types of maltreatment and four referrals to DCFS.

The comparison group ($n=151$) was recruited using names from school lists of children aged 9–12 years residing in the same 10 zip codes as the maltreated sample. Caretakers of the potential participants were sent a postcard and asked to indicate their interest in participating, which was followed up with a phone call.

Upon enrollment in the study, the maltreatment and comparison groups were compared across a number of demographic variables. The two groups did not differ significantly in age, race, gender, and neighborhood characteristics. On average, children in the sample at Time 1 were 10.93 years old ($SD = 1.16$). Approximately 53% of the children were male, 38% African American, 39% Latino, 12% Biracial, and 11% Caucasian. However, the children were different in terms of living arrangements. In the comparison group, 93% lived with a biological parent, whereas this was the case for only 52% of the maltreatment group. The remainder of the maltreatment group was living in foster care, which is not unusual for adolescents involved with social services. To confirm the maltreated and comparison group were adequately matched in terms of living conditions and neighborhood characteristics, the two groups were compared using the 2000 U.S. Census (Trickett, Mennen, Negriff, & Horn, 2011). We used addresses of the homes in which the children were living (for the maltreated children, it was the address where they were living at the time of the referral to DCFS). Specifically, we compared these addresses in terms of the smallest geographic unit of the Census, namely, the Census Block Group. Comparisons were made using nine census categories relevant to characterizing the social, educational, economic, and demographic nature of the neighborhoods in question and those deemed important for child development (Duncan & Aber, 1997). Independent-samples t -tests were conducted for each category of each census characteristic. For example, for the dimension “Percent of People of Different Ages,” two-group (maltreatment vs. comparison) t -tests were performed for each of 10 age categories. For this set of comparisons, a statistically significant difference was found for one age category (percent of 40- to 49-year-olds), where the average of 12% in the maltreated group differed statistically from the 13% in the comparison group. In 72 comparisons of this kind, nine statistically significant differences were found. Similar to the difference previously reported, none of these differences were large, or if there were differences, they were theoretically unimportant and not likely to produce an effect through a relation with other variables. The range of differences among the samples in percentages for the 72 comparisons of the nine characteristics was from 1% to 4% (with a median of 2%). This indicated that, overall, for the dimensions examined, the neighborhoods of the maltreatment group and the comparison group were very similar.

Attrition

The attrition rate between Time 1 and Time 2 was 13.4% ($n=61$); between Time 1 and Time 3, it was 31% ($n=141$). Two separate binary logistic regression analyses were performed to test whether attrition at Time 2 and Time 3 were random. The dependent variable for the attrition analysis was a dichotomous variable (yes, no) indicating attrition at Time 2 and Time 3. Time 1 pubertal timing variables and demographic variables were entered to predict the dropout rate of participants during the longitudinal assessment. The results of the attrition analyses indicated that the participants who were not seen at Time 2 were more

likely to be in the maltreatment group ($OR=4.38, p<.01$), and those not seen at Time 3 were more likely to be Latino ($OR=3.37, p<.01$) and in the maltreatment group ($OR=5.36, p<.01$).

Procedures

Assessments were conducted at an urban research university. After assent and consent were obtained from the adolescent and caretaker, respectively, the adolescent was administered questionnaires and tasks during a 4-hour protocol that included a break for the adolescent and caretaker to reduce fatigue effects. The measures used in the following analyses represent a subset of the questionnaires administered during the protocol, which also included hormonal (i.e. cortisol), cognitive, and behavioral measures. Both the child and caretaker were paid for their participation according to the guidelines of the National Institutes of Health standard compensation rate for healthy volunteers.

Measures

Pubertal Development

Pubertal stage was measured using the Pubertal Development Scale (PDS), which is a measure of the physical changes associated with pubertal development. It was developed as an alternative to physician rating measures and has been shown to have adequate reliability and validity when self-perception of pubertal development is appropriate for the research questions at hand (Petersen, Crockett, Richards, & Boxer, 1988). On a 4-point scale ranging from 1 (*has not yet started*) to 4 (*has completed*), each participant was asked to indicate the level of development on each of a set of physical changes. In the present study, five items were used for both females and males (height spurt, body hair, skin changes, breast growth or deepening of voice, and menarche or facial hair), and the total scores were computed. A coding system developed by Shirtcliff and colleagues (Shirtcliff, Dahl, & Pollak, 2009) was used to convert the PDS scores to a 5-point scale that parallels the Tanner stages. The converted PDS scores have been shown to correlate highly with hormonal measures of puberty. In order to draw inferences about early life experiences altering the HPA or HPG axes, it follows that external pubertal development should be operationalized in a way that closely matches the physiological development. The Shirtcliff-scored PDS was used as the indicator of pubertal development in the present study, with a possible range of 1–5. A score of 2 on this scale indicated onset of puberty.

Maltreatment Classification

For the maltreatment classification, data were obtained from child welfare case records that described the children's maltreatment experiences. Trained research assistants abstracted information relating to maltreatment to classify the types of maltreatment experienced (see Trickett, Mennen, Kim, & Sang, 2009 for details of the record abstraction). Categories included neglect ($n = 232$), emotional abuse ($n = 156$), physical abuse ($n = 156$), and sexual abuse ($n = 60$). Maltreatment was coded as the presence or absence of that particular type of abuse, resulting in four separate maltreatment variables that were not mutually exclusive. That is, these variables do not account for co-occurring maltreatment types; an adolescent could be included in all four types of maltreatment categories. The data showed that 76% of

the maltreatment group experienced more than one type. The maltreatment classification was determined at Time 1 and remained constant across times.

Results

Aim 1: Pubertal Trajectories

Variable-Centered Analyses—Because we were interested in pubertal changes across chronological age, we used age as the basis rather than the time of data collection (McArdle, 2010). That is, for all analyses, data were arrayed by age rather than time point. Descriptive statistics and correlations (separate for boys and girls) for pubertal development across age can be found in Table 1 and Table 2. To establish the average developmental trajectory, we first ran a series of unconditional growth curve analyses ranging from a no-growth model to a quadratic-growth model. In all models, parameter estimates were obtained using full information maximum likelihood (FIML) in Mplus (L.K. Muthén & B.O. Muthén, 2006). Time was centered at age 10. Therefore, the intercept in all models reported in this paper represents pubertal timing at age 10. In these models, tempo was indicated by the slope (rate of change over age) in conjunction with any quadratic effects (change in the rate of change). That is, the slope specified the average changes in pubertal stage per year, and the quadratic effect specified whether the yearly rate of change was stable (indicated by a non-significant quadratic term), sped up (indicated by a positive quadratic term), or slowed down over time (indicated by a negative quadratic term). Goodness-of-fit indices were used to make decisions about the accuracy of the models. More specifically, we relied on the overall chi-square, the root mean square error of approximation (RMSEA; Browne & Cudeck, 1993), and comparative fit index (CFI; Bentler, 1990) for the assessment of good fit.

For boys, an unconditional quadratic growth model fit better than the linear and no-growth models ($CFI = 1.00$, $RMSEA = .01$, $\chi^2 = 10.22$, $df = 10$). However, the quadratic variance had to be fixed at 0 to avoid problems with singularity. Although this resulted in a decrease in model fit, the fit was still better for the quadratic model ($CFI = .77$, $RMSEA = .06$, $\chi^2 = 23.61$, $df = 13$) than the linear and no-growth models. At age 10, boys were in stage 1.75, on average. The linear increase was .13 stages per year from age 10 to 14, which was non-significant, suggesting that boys are just beginning to develop at age 10. However, the quadratic effect (.06) was significant, suggesting an acceleration in their rate of growth during this age period (See Figure 1).

For girls, the quadratic model fit better than the other unconditional models ($CFI = .90$, $RMSEA = .05$, $\chi^2 = 15.21$, $df = 10$). However, the variances of the slope and quadratic parameters were fixed at zero due to problems with singularity. This resulted in a reduction in fit compared with the unrestricted model ($CFI = .56$, $RMSEA = .08$, $\chi^2 = 36.88$, $df = 15$), but the fit was better than the linear and no-growth models. At age 10, girls were in stage 1.89 on average. Both the linear as well as quadratic terms were significant. Girls are changing by .57 ($p < .05$) stages per year, but there is a deceleration (quadratic = $-.04$, $p < .05$) in their rate of change from 10 to 14 years, meaning that girls are slowing down in their rate of increase (See Figure 1).

Person-Centered Analyses—In the variable-centered analyses, the focus was on determining the overall average growth pattern across the total sample. However, it may be the case that there are different groups of adolescents who fit different pubertal trajectories. We tested this hypothesis using latent class growth analysis (B.O. Muthén & L.K. Muthén, 2000). Latent class growth analyses allow for the determination of whether different groups of adolescents have different growth trajectories and provide estimates of class probabilities along with estimates of an individual's most likely class membership (B.O. Muthén, 2001; B.O. Muthén & L.K. Muthén, 2000). We tested linear and quadratic models, increasing the number of classes from 1 to 4 using the MPlus statistical program (L.K. Muthén & B.O. Muthén, 2006). That is, we examined whether there may be some adolescents who follow linear trajectories, whereas other adolescents show no growth or follow a quadratic trajectory over age. Decisions about the optimal number of classes were based on the entropy (Ramaswamy, Desarbo, Reibstein, & Robinson, 1993), Bootstrap Likelihood Ratio Test (BLRT), and the Bayesian information criterion (BIC) (Jung & Wickrama, 2008), along with theoretical considerations. All models were tested separately for boys and girls.

For boys, the best-fitting model was a three-class quadratic solution in which the variance of the quadratic parameter was freely estimated (see Table 3 and Figure 2). Although the four-class solution had a lower BIC than the three-class solution, the BLRT was not significant, indicating that the four-class solution was not significantly better than the three-class solution. Classes, which differed in their timing or tempo (rate of change), were labeled based on pubertal status at age 10 and relative rate of change when compared with the other classes. The boys in Class 1 ($n = 21$) had a later pubertal onset with faster development in the later years (*later timing-faster tempo*); the intercept ($1.00, p < .01$), linear ($-.23, p < .01$), and quadratic parameters ($.22, p < .01$) were all significant for Class 1. The intercept ($1.83, p < .01$), linear ($-.55, p < .01$), and quadratic parameters ($.20, p < .01$) were also significant for boys in Class 2 ($n = 96$); however, the boys in Class 2 demonstrated an earlier timing of puberty relative to Class 1. Boys in Class 2 also showed a more gradual rate of change. We, therefore, categorized this class as *earlier timing-gradual growth*. Finally, for boys in Class 3 ($n = 122$), only the intercept ($1.96, p < .01$) was significant. These boys experienced earlier timing with no significant growth occurring at age 10 and were, therefore, classified as *earlier timing-stable tempo*.

For girls, linear models with fixed intercepts and slope variances provided a better representation of the data than the quadratic models. Although the three- and four-class solutions had higher entropy values, the two-class solution had the lowest BIC value. Moreover, the BLRT values for the three- and four-class solutions were not significant (see Table 3). Therefore, the two-class solution was selected (See Figure 3). The intercept ($1.35, p < .01$) and linear ($.46, p < .01$) parameters were significant for Class 1 ($n = 88$, *later timing-faster tempo*). In contrast, girls in Class 2 ($n = 118$) started earlier (intercept = $2.38, p < .01$) but experienced a slightly slower tempo ($slope = .40, p < .05$, *earlier timing-slower tempo*).

Aim 2: Maltreatment as a Predictor of Pubertal Development

Variable-Centered Analyses—Although the slope and quadratic parameter variances had to be fixed at zero to avoid problems with singularity (see D. Huang, Brecht, Hara, &

Hser, 2010) in the variable-centered analyses, we felt it important to examine maltreatment as a predictor in an exploratory manner given that little research has been conducted on this topic. This approach is similar to that taken by others in the field (e.g., Mendle et al., 2011). Thus, conditional quadratic growth models were run where the growth parameters were predicted from neglect, emotional abuse, physical abuse, and sexual abuse with each maltreatment type examined separately. In each of these models, two dummy-coded variables were entered so that individuals in the focal maltreatment category served as the reference group. For example, in the analyses with sexual abuse as the predictor, one dummy-coded variable allowed for a comparison between adolescents who had experienced sexual abuse and the comparison group. The second dummy-coded variable allowed for a comparison between adolescents who had experienced sexual abuse and adolescents who had experienced other types of maltreatment.

The fit statistics for the conditional models for boys and girls are shown in Table 4. For boys, emotional, physical, and sexual abuse did not predict the growth parameters. However, there was a significant effect for neglect status. Specifically, there were significant differences between the boys who experienced neglect versus those who experienced other types of maltreatment in their tempo of puberty (or rate of change over age). The mean rate of pubertal change for the boys who had experienced neglect was not significant ($b = -.10$, ns). In contrast, the rate of change for the boys who had experienced other types of maltreatment was positive and significant ($b = .52$, $p < .05$); thus, boys who had experienced neglect were changing at a slower rate at age 10 than the boys who had experienced other types of maltreatment. However, neglect status was also found to have a significant effect ($p = .013$) on the quadratic parameter when comparing boys who had experienced neglect with their counterparts who had experienced other types of maltreatment. As can be seen in Figure 4, boys in the neglected group started out slowly in their development but then had an increase in tempo later in adolescence. In contrast, the boys who had experienced other types of maltreatment started out with a faster tempo early in adolescence that slowed later on. Boys in the comparison group did not differ from the boys who had experienced neglect.

Results for girls differed from those for boys. Specifically, the conditional quadratic growth models fit worse than the unconditional model (see Table 4). Additionally, none of the maltreatment types were significant predictors of the pubertal growth parameters for girls.

Person-Centered Analyses—After identifying the different classes for boys and girls, an individual's most likely class membership was used in subsequent chi-square analyses to test maltreatment type as a predictor of class membership. Analyses were conducted separately for each maltreatment type within each gender. For boys, there were no significant effects. That is, maltreatment type did not predict trajectory class for boys. For girls, there was a significant effect for sexual abuse (see Table 5). Of the 39 sexually abused girls, 71.8% were in the earlier-timing class. In contrast, of the 105 other maltreated girls, 48.6% of them were in the earlier-timing class. Thus, girls who experienced sexual abuse were more likely to be in the earlier-timing class when compared with girls who had experienced other types of maltreatment. Girls in the comparison group did not differ from those who had experienced sexual abuse or those who experienced other types of maltreatment in terms of timing and tempo.

Discussion

The pubertal development literature is relatively inundated with evidence that timing of puberty has unique and robust effects on mental health and behavior problems for adolescents (for a review, see Negriff & Susman, 2011). However, few studies have incorporated the timing of puberty at one timepoint with the progression of puberty across the entire pubertal transition (i.e., tempo). The present study examined timing and tempo simultaneously, using both a person-centered and variable-centered approach to identify trajectories of pubertal growth. Maltreatment type was investigated as a predictor of different patterns of pubertal development.

A strength of the present research is the use of two techniques to understand individual differences in the developmental trajectory of puberty. Very rarely have both variable-centered and person-centered analyses been conducted to address the same research question with the same sample, and even less so in the field of pubertal development. Variable-centered analyses allow us to understand group averages, which, in this case, was the average pubertal development of the adolescent. However, results in the present study revealed that not all adolescents fit the average trajectory, and the use of the person-centered approach allowed for a more fine-tuned understanding of pubertal development. Using the person-centered approach, we determined whether there were different patterns of pubertal growth in the adolescent years. Early life experiences may alter the development of puberty across adolescence, which may not be captured by a snapshot, or average, measurement of pubertal timing and tempo. The pubertal timing literature has primarily used variable-centered approaches when examining the antecedents of early puberty. The person-centered approach, together with the variable-centered approach, provides a more comprehensive perspective.

Specifically, the results from the variable-centered analyses showed that quadratic models were the best fit to the data, and neglect had a significant effect on the quadratic growth parameter for boys. The interpretation of this finding is that boys who experience neglect were slower in their initial pubertal development but then accelerated as they got older. This tempo effect differs from that of boys who experienced other types of maltreatment; these boys demonstrated a faster initial tempo that slowed in mid-adolescence. Interestingly, the comparison group showed a growth trajectory that was between the two other groups and not significantly different from the adolescents who had experienced neglect. Additionally, there were no significant differences in the intercepts, indicating that the age at onset was similar for the three groups. The differences in tempo may have emerged from their home experiences; that is, neglected boys may experience more impoverished environments, poorer nutrition, and lack of medical care (Mennen, Kim, Sang, & Trickett, 2010), all factors associated with stunted physical growth and the delay of puberty. Evidence indicates that low resources are linked with delayed puberty in females (Ellis, 2004) and the present findings provide some support for a similar association for males. Whether the effect of neglect on pubertal development is through availability of resources or alteration of the stress system, the findings demonstrate that, for boys, neglect is substantively different than other forms of maltreatment. This is bolstered by the fact that the majority (76%) of the neglected boys also had experienced at least one other type of maltreatment, indicating that

even in the presence of other maltreatment, neglect has over-riding effects on the tempo of puberty.

In contrast to the variable-centered analyses, the person-centered analyses focused on identifying classes or groups of adolescents who fit similar growth patterns across adolescence. For boys, the results indicated three classes. Two of the classes had the same pubertal onset (timing) but different tempos. The third class had a later onset with more rapid development across adolescence. Class 2 appeared to initially decrease in pubertal stage. This may be an artifact of self-reported pubertal development, with some boys ($n=3$) over reporting early development and then reporting more accurately later on. Moreover, the difference between age 10 and age 11 status was not statistically significant. The obtained classes were named relative to the other classes, not using national norms for pubertal development. Therefore, we make no assertions about mapping these classes onto typical or atypical patterns of pubertal development.

For girls, there were two classes: one with earlier timing but a slower tempo and another with later timing and a faster tempo. Unlike the classes found for boys, timing and tempo were confounded in the classes for girls. The later-timing girls were also faster in tempo, and the earlier-timing girls were also slower in tempo. Therefore, for girls, when speaking about timing, we are also speaking about tempo. This contrasts the findings for boys where we could differentiate timing from tempo. It may be that variance in timing and tempo was not as apparent for girls as for boys in the present sample because of the initial age in our analyses. On average, girls start puberty earlier than boys. Thus, studying girls at earlier ages may result in greater variability in classes than was obtained in the present research.

In addition, we found that maltreatment type predicted class membership for girls. Specifically, sexual abuse predicted membership in the early timing class compared with adolescents with other types of maltreatment. This is consistent with several studies that find that sexual abuse is a risk factor for early puberty above and beyond other types of maltreatment (e.g., physical abuse or neglect) (Brown et al., 2004; Mendle et al., 2011; Wise, Palmer, Rothman, & Rosenberg, 2009). However, girls who had experienced sexual abuse were not more likely than the comparison girls to be in the early timing class. It may be that some of the adolescents in the comparison group were victims of unreported sexual abuse, which is an important variable to consider in future work. Overall, the results for girls clarify the effect of maltreatment type on pubertal timing because other studies have found maltreatment, in general, to be related to early puberty (Costello et al., 2007) or found effects of sexual abuse in the absence of a comparison group (Mendle et al., 2011).

Together, the variable-centered and person-centered analyses demonstrate that maltreatment experiences do not have universal effects on the pubertal development of both genders. Moreover, the finding that the two-and three-class models fit better than the single-class models suggests that there is added value in the use of person-centered approaches to understand pubertal development. In particular, the person-centered approach can help us to better understand what determines one pubertal development pattern versus a different pattern through prediction of the classes, as was done in the present study. When we can better predict why one child develops at one rate versus another rate, this can subsequently

help us to begin to address outcomes related to pubertal timing and tempo, such as internalizing and externalizing disorders. Additionally, the results regarding maltreatment types contribute to our understanding of gender differences in differential susceptibility to early life experiences that may alter the timing and rate of pubertal development. More research is required to determine whether the results obtained in the present research can be replicated to continue enhancing our understanding of the impact of maltreatment experiences on adolescent pubertal development.

There are several limitations of the present research that should be acknowledged. First, the measure of pubertal development was by self-report rather than by physician report, which may result in reporting errors. Indeed, there does appear to be errors in reports of pubertal development in the present sample, particularly for some boys who seemed to initially decrease in pubertal stage across ages 10–14 (Class 2). Additionally, the PDS was converted to parallel the Tanner Stages, an approach that may increase error. A further limitation is that we were not able to account for co-occurring types of maltreatment; the analyses compared adolescents who had experienced a specific type of maltreatment with all adolescents who had not experienced that type. The expectation, based on previous research, was that sexual abuse would emerge as a significant predictor of early puberty, which was only the case for girls. It may also be that certain combinations of maltreatment or characteristics (e.g., severity or chronicity) might better explain variation in pubertal development.

Despite the limitations, the results of the present study contribute to our knowledge of timing and tempo of pubertal development across adolescence. Importantly, boys and girls are neither similar in the patterns of pubertal development nor in the aspects of maltreatment that predict pubertal growth. Furthermore, the results of the latent class analysis indicate that within gender, there is still substantial variability in trajectories of pubertal growth. More specifically, the results suggest that sexual abuse may have more of an effect on pubertal timing for girls than boys, with the caveat that there were only 20 boys in the sample who had been victims of sexual abuse, which inherently reduced the power to detect significant effects. However, neglect has a more adverse effect on the initial development of boys, who seem to have slower tempo in early adolescence. Clearly, further investigation needs to be conducted into the specific nuances of maltreatment experience and the effects on pubertal timing and tempo. A next step may be to examine pubertal timing and tempo as mediators between early maltreatment and later problem behavior. Understanding the early life experiences that place an individual at risk for a pattern of pubertal development that may lead to problems later in adolescence is integral for curtailing maladaptive developmental trajectories.

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Figure 1.
Variable-Centered Growth Model for Boys Versus Girls

Figure 2.
Three-Class Model for Boys

Figure 3.
Two-Class Model for Girls

Figure 4.
Variable-Centered Growth Model by Neglect Status for Boys

Table 1

Descriptive Statistics for Pubertal Development Across Age

Girls												
Boys												
Variable	<i>M</i>	<i>SD</i>	Range	Skewness	Kurtosis	<i>N</i>	<i>M</i>	<i>SD</i>	Range	Skewness	Kurtosis	<i>N</i>
Age 10	1.78	0.77	1.00-4.50	1.15	1.34	86	1.94	0.69	1.00-3.50	.46	-.55	78
Age 11	1.94	0.79	1.00-4.50	.67	-.23	113	2.31	0.86	1.00-5.00	.52	-.02	113
Age 12	2.23	0.93	1.00-4.50	.41	-.79	143	2.84	0.85	1.00-5.00	.16	-.54	126
Age 13	2.67	1.00	1.00-5.00	.08	-1.03	123	3.39	0.79	1.00-5.00	-.04	-.29	98
Age 14	3.08	0.91	1.00-4.50	-.39	-4.10	67	3.49	0.57	2.50-5.00	.44	-.17	62

Table 2

Correlations for Pubertal Development Across Age

Variable	1	2	3	4	5
1. Age 10	1.00	.55**	.37*	.28	-.46
2. Age 11	.19	1.00	.40**	.30	.00
3. Age 12	-.01	.40**	1.00	.48**	.45**
4. Age 13	.29	.45**	.44**	1.00	.28
5. Age 14	-.91	-.16	.24	.51**	1.00

Note.: Correlations for boys are in the lower diagonal.

Correlations for girls are in the upper diagonal.

* $p<.05$.
** $p<.01$.

Table 3

Fit Statistics for Latent Class Growth Models for Boys and Girls

Number of Classes	Entropy	BIC	BLRT
Boys			
1	NA	1,394.92	NA
2	.59	1,347.33	74.97, $p < .05$
3	.71	1,287.62	87.10, $p < .05$
4	.78	1,285.91	29.10, ns
Girls			
1	NA	1,139.99	NA
2	.56	1,103.32	57.98, $p < .05$
3	.72	1,112.42	12.21, ns
4	.67	1,129.87	11.88, ns

Note. BIC = Bayesian information criterion; BLRT= Bootstrap Likelihood Ratio Test.

Table 4

Fit Statistics for Variable-Centered Conditional Growth Models for Boys and Girls

Model	Chi-square	RMSEA	95% CI	CFI
Boys (<i>df</i> = 17)				
Emotional abuse as a predictor	24.87	.04	.00, .08	.84
Physical abuse as a predictor	28.40	.05	.01, .09	.74
Sexual abuse as a predictor	25.41	.05	.00, .08	.79
Neglect as a predictor	26.43	.05	.00, .08	.80
Girls (<i>df</i> = 19)				
Emotional abuse as a predictor	50.14	.09	.06, .12	.45
Physical abuse as a predictor	49.20	.09	.06, .12	.46
Sexual abuse as a predictor	48.19	.09	.06, .12	.51
Neglect as a predictor	49.76	.09	.06, .12	.47

Note. RMSEA= root mean square error of approximation; CI= confidence interval; CFI= comparative fit index.

Table 5

Cross-tabulation of Maltreatment Status and Pubertal Class for Girls

Pubertal Class	Maltreatment Status		
	Comparison	Other Maltreated	Sexual Abuse
Earlier timing	39 ^{a, b} (63.9%)	51 ^b (48.6%)	28 ^a (71.8%)
Later timing	22 ^{a, b} (36.1%)	54 ^b (51.4%)	11 ^a (28.2%)

Note: Each subscript letter denotes a subset of maltreatment category whose column proportions do not differ significantly at the .05 alpha level.