

Transitions in body and behavior:

A meta-analytic study on how pubertal status and timing are related to adolescent sexual behavior
and sexual risk behavior

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Abstract

Purpose: The current meta-analysis studies the relations of pubertal timing and status with sexual behavior and sexual risk behavior among youth aged 10.5-24 years old. We included biological sex, age, and ethnicity as potential moderators.

Methods: Four databases were searched for studies (published between 1980 and 2012) on the relation between pubertal timing or status and sexual behavior. The outcomes were a) sexual intercourse, b) combined sexual behavior, and c) risky sexual behavior.

Results: Earlier pubertal timing or more advanced pubertal status was related to earlier and more sexual behavior, and earlier pubertal timing was related to more risky sexual behavior. Further, the links between (1) pubertal status and combined sexual behavior, (2) pubertal timing and sexual intercourse status and risky sexual behavior were stronger for girls than for boys. Most links between pubertal status, timing, and sexual behavior and sexual risk behavior were stronger for younger adolescents. Moderation by ethnicity did not yield consistent results.

Conclusions: There was significant variation in results among studies that was not fully explained by differences in biological sex, age, and ethnicity. Future research is needed to identify moderators that explain the variation in effects and to design sexual health interventions for young adolescents.

Key words: Pubertal timing; Pubertal status; Adolescent; Sexual behavior; Sexual risk behavior; Meta-analysis

Implications and contribution

Research comparing the effects of pubertal status and timing across different sexual outcomes is lacking. This meta-analysis gives a systematic overview of research examining these links. Early developing adolescents engage in earlier and more (risky) sexual behavior—these effects were consistently stronger for girls.

Recent perspectives on adolescent development view sexual development as a normative task of this life phase [1]. However, the early initiation of sexual behavior has also been linked with increased risk for unwanted pregnancies, sexually transmitted infections and depression [2-3]. Given the obvious link between pubertal development and sexual reproduction capacity, the onset of puberty has been associated with the initiation of sexual desires and behavior. Less clear is to what degree pubertal development is related to sexual activity and whether early pubertal development is particularly problematic for the development of risky sexual behavior.

Although qualitative reviews and a large body of quantitative work have shown support for the relationship between pubertal timing and sexual development, no meta-analytic review exists that quantifies the magnitude of this relationship or that explains variation in results across studies. Moreover, while most studies focus on whether (vaginal) sexual intercourse has occurred, sexual development consists of a broad range of physical behaviors besides intercourse including activities such as kissing, petting, and oral sex. The primary objective of the current meta-analysis is to examine and quantify the association between pubertal status and timing with non-risky and risky coital and non-coital sexual behaviors.

Not only do studies vary in terms of the sexual behaviors examined, but there is also substantial variation in how pubertal status and timing are assessed. Pubertal status is most often measured using (1) Tanner scale ratings made by trained professional of adolescent pubic hair development (males and females), and breast development (females) or penis and testicular development (males), (2) adolescent self-report of these characteristics using photographs or line drawings, or (3) questionnaire measures of pubertal characteristics (growth spurt, acne, pubic hair, menarche, voice change). Pubertal timing is often assessed using (4) adolescent self-report of age at growth spurt, age at first ejaculation or voice change (males), or age at menarche (females), (5) age adjusted measures of pubertal status (stage-normative), or (6) adolescent self-perceptions of whether their pubertal development is early, on-time or late (peer-normative). There is moderate consistency across these different methods, however, the degree to which adolescents rate

themselves as more or less developed than their peers might not just reflect their physical development, but might also reflect the degree to which they feel psychologically or behaviorally more mature [4-6]. Therefore, the second objective is to compare whether the magnitude of the association between pubertal development and sexual behavior and risky sexual behaviors depends on how pubertal development was assessed.

Drawing from a developmental systems approach which acknowledges that development in one domain (such as sexual development) does not occur independent from other domains (such as the social domain), we also examine whether the relation between pubertal and sexual development is also associated with individual differences in age, sex, or ethnic background. Previous research has shown that boys and girls show different patterns of pubertal development [7] and these differences are also suggested to relate to differences in social status and well-being [2, 3,8-10]. Therefore, in the current meta-analysis, we examine whether the effects of pubertal status and timing on sexual behavior and sexual risk behavior are different for boys and girls. Further, as adolescents move from a parent- to a peer-focused context during adolescence [11], they are faced with more opportunities to engage in intimate and sexual behavior. Therefore, we also examine whether the effects of puberty on adolescents' sexual development vary depending on the adolescents' age. The link between pubertal development and sexual behavior might be stronger at younger ages, particularly in risky sexual behavior, because younger adolescents may not have the social and cognitive skills to engage in safer sexual behavior. However, stronger effects might be also found in older adolescents because they are less restricted by parents. Finally, research has shown several inconsistent racial and ethnic differences in pubertal [7,12] and sexual development [13-14]. Therefore, we examine whether these links are moderated by the ethnic background of adolescents.

The Current Study

The primary objective of the current meta-analysis is to examine and quantify the association between pubertal status and timing with sexual behavior and risky sexual behavior.

With this meta-analysis, we answer the following questions: Within the research literature published between 1980 and 2012, are pubertal timing and status related to) sexual behavior and sexual risk behavior? If related, is this relation moderated by the way pubertal development is assessed (pubertal status or pubertal timing and stage-normative or peer-normative), or the age when pubertal development was assessed sex, and ethnicity?

Although initially our intention was to study differential effects of pubertal development on a range of sexual behaviors, most studies have examined either only sexual intercourse or have lumped together several sexual behaviors. Therefore, we have made the distinction between three sexual behavior categories: 1) sexual intercourse status (had sexual intercourse or not) and age at first sexual intercourse, 2) combined sexual behavior (studies that include sexual intercourse *and* non-coital sexual behaviors, in their combined measure of sexual behavior), and 3) sexual risk behaviors such as a combined measure of sexual risk behavior, unwanted pregnancy, contracting sexually transmitted infections (STIs) or HIV, non-condom/contraception use, and drug/alcohol use during sex.

Method

Sample of Studies

We searched four electronic databases (Scopus, Medline, Web of Science, and Psycinfo) using variations and Boolean connections of the key terms *pubertal development*, *menarche*, *spermarche*, *spermatogenesis*, *breast development*, *andrenarche*, *gonadarche*, *oogenesis*, *adolescents*, and *sexual behavior*. To supplement these searches, we searched reference lists of reviewed studies and contacted key authors in the field. To be included in the meta-analysis, studies had to be: (a) published in a peer-reviewed, English language journal; (b) empirically examine and report the relation between pubertal development and adolescents' (risky) sexual behaviors; (c) be published between January 1980 and December 2012; and (d) include adolescents with a mean age no older than 24 years old.

Information extracted from each study included: (1) age, sex, and/or ethnicity of sample; (2) pubertal development measure(s); (3) sexual behavior measure(s); and (4) effect size(s). Thirty percent of the studies were independently coded by two coders (including the first author). Intra-rater reliability was good (correlations ranged from .68 to .99). Any inconsistencies in the coding were checked by another independent coder and reconciled. Data were entered into SPSS 20.0 and analyzed with the SPSS macro [15].

First, effect sizes were calculated or recoded using the Pearson product-moment correlation (r) such that higher r values indicated a stronger relation between pubertal status or timing, and (risky) sexual behavior. If a study reported results on group-differences (t , F , or odds/risk ratio), their results were converted to r [15]. Second, all r values were converted to Fisher's Z (Zr). Third, for each effect size we calculated a relative weight for Zr , taking into account sample size. To yield an interpretable overall effect size, the weighted mean effect size was then converted back to r (ESr).

Pubertal development

Pubertal status. Several studies included self-report occurrences of physical pubertal events (e.g., first spontaneous nocturnal emission, menarche, Tanner drawings [16-17], Pubertal Development Scale [18], Index of Adolescent Development, or ratings of physical maturity by coders [19] as markers of adolescents' pubertal status. Some studies ($k=5$) reported using a pubertal status measure, in a sample of same-aged participants. Using a measure of pubertal status among same-aged participants does not just assess how advanced someone is in their pubertal development, rather it creates a measure of pubertal timing by assessing how far advanced someone is in their pubertal development compared to their same-aged peers. Therefore, these studies were coded as using a pubertal timing measure.

Pubertal timing. Most studies used one of three ways to assess pubertal timing: (1) a self-report measure of adolescents' perceptions of pubertal timing (i.e., "Is your pubertal development early or late compared to peers?"), (2) age at menarche, or (3) the PDS total score adjusted for age

(that is, the total score was converted to a z score within each age and gender group). Those studies that reported a comparison between early versus on-time ($k=3$), or on-time versus late ($k=3$) were also included and recoded such that a positive relation would indicate a stronger effect for the early (compared to on-time) or the on-time (compared to late) group. We classified studies as using a “stage-normative” measure of pubertal timing based on self-reported pubertal status ($k=38$), when for example, the PDS or physical ratings of adolescent’s appearance was used. We classified other studies as using a “peer-normative perceived” measure of pubertal timing when youth reported on his or her perception of their own pubertal timing in comparison to peers ($k=26$). In our analyses we tested whether the links to sexual behavior and sexual risk behavior were moderated by the measure of pubertal timing (stage-normative vs. peer-normative). We analyzed studies using age at menarche separately from the other studies.

Sexual development

Sexual intercourse. All studies used a self-report measure of either age at first sexual intercourse or sexual intercourse status. Most studies did not define sexual intercourse and if they did, they defined it as vaginal sexual intercourse. For the inclusion of studies under the category of sexual intercourse, they either had to use the term “sexual intercourse”, or explain sexual intercourse as vaginal sexual intercourse. The studies that did not include sexual intercourse in their sexual behavior measure, or combined those with other sexual behaviors, were included under “combined sexual behavior.”

Combined sexual behavior. Several self-report measures were used to assess behaviors other than or in addition to sexual intercourse. Only 6 studies used a combined sexual behavior that did not include sexual intercourse. These studies used measures on self-reports of non-coital sexual behavior such as petting, kissing, caressing, and oral sex. There were 30 studies that used a combined measure of non-coital sexual behaviors *and* coital sexual behaviors. We grouped these two categories together (purely non-coital and combined coital and non-coital) into the combined sexual behavior measure. To explore whether the inclusion of purely non-coital ($k=6$) and combined

coital and non-coital measures (k=30) made a difference in relation to pubertal development we tested the moderation of these two forms of measuring combined sexual behavior. There was only one study [20] that reported on the link between pubertal development and individual (non-coital) sexual behavior (e.g., kissing and caressing) and therefore we were unable to do separate analyses on specific behaviors.

Risky sexual behavior. Measures of risky sexual behavior included questions about unwanted pregnancy, contracting STIs/HIV, non-condom/contraception use, and drug/alcohol use during sex. Some studies included a measure of risky sexual behavior that comprised multiple risky behaviors. The number of studies examining different categories of risky sexual behavior measures was too small to analyze separately.

Moderators

Age. For age we, included the mean age of the sample; If not reported, we took the mean age of the reported range of ages.

Sex. Studies were classified according to the sex composition of the sample: a) boys, b) girls, and c) mixed. In our moderator analyses we used dummy variables (boys versus girls; mixed versus girls; and mixed versus boys) to compare the different samples.

Ethnicity. Unfortunately, there were only 2 studies that reported results separately for ethnic groups other than Black participants. One study had results reported separately for White and Latina girls [13], the other only included Hispanic girls in their study [21]. Most studies include a wide range of ethnic backgrounds in their sample, with the most predominant ethnic groups being White or Black. Further, some studies reported results separately for White and Black adolescents. Therefore, for the current study, we were only able to examine differences in the associations between pubertal development and sexual behavior and sexual risk behavior between Black or White adolescents. Thus, for ethnicity we included the percentage of “Black” adolescents in the sample *if* this was reported. If, in a study, it was reported that a sample was 100% White, this was coded as zero percent Black participants. Enough studies were found to examine four relations:

pubertal status and pubertal timing with and sexual intercourse status; pubertal timing with combined sexual behavior; and age at menarche with age at sexual intercourse.

Data Analyses

To examine the heterogeneity of effect sizes across studies we assessed the Q statistic. This statistic indicates the variability across effects sizes that may be explained by other sources and indicates the need to examine moderators, if this statistic is significant [15]. We analyzed the data using fixed effect models and random effects models. Because the current meta-analysis includes small samples of effect sizes, we only report the fixed effect model results.¹ We examined sex, age, and ethnicity of the sample, stage-normative versus peer-normative measure of pubertal timing, and purely non-coital combined sexual behavior versus combined sexual behaviors that included coitus as potential moderators in the relation between pubertal status or timing and (risky) sexual behavior. The moderation analyses yielded Betas that when significant indicate an interaction between the moderator and predictor (pubertal status or timing) in their effect on the sexual behavior outcomes.

Results

Description of Studies: Overview of Included Studies

Initially, 70 studies were found. In total, 50 independent studies met the inclusion criteria, with a total of 112 effect sizes. Table 1 presents the included studies across the separate meta-analyses. Samples included a total of 87,334 adolescents (min=41, max=5700). The mean ages of the adolescents in these studies ranged from 10.5 to 22.4 years, with an overall mean of 15.10 years ($SD=2.82$). Of the included effect sizes, 51 were all girl samples, 32 all boys samples, and 29 were mixed samples. Of these, most ($k=71$) were from the USA, see Table 1.

Results of the Separate Meta-Analyses

In what follows, we show correlational effect sizes (ES_r) that emerged from our meta-analysis, and whether the relations between pubertal development and sexual behavior and sexual risk behavior were moderated by pubertal timing measure, coital or non-coital sexual behavior measure, sex, age, and ethnicity of the sample (see Tables 2 for the overall effect size and

heterogeneity analyses). Only if the Q-statistic was significant (heterogeneity of effect sizes), was it necessary to conduct moderation results (Table 3). For discontinuous moderators (sex, pubertal timing measure, and coital or non-coital behavior), we report the effect size and confidence intervals per group in Table 4. For continuous moderators, we report the Beta of the moderation in Table 3 and the direction of effects in text.

Pubertal Status and Sexual Behavior and Risky Sexual Behavior

Sexual intercourse. There was only one study that examined the link between pubertal status and age at sexual intercourse [34], and another that studied the link between menarcheal status and sexual intercourse status [51]. Both studies found a significant small positive association between status and sexual intercourse ($ESr=.11$ and $ESr=.19$, respectively). No further analyses were conducted using these studies.

With a meta-analysis on 5 effect sizes, the results showed a small to moderate positive link between pubertal status and intercourse status ($ESr=.20$). That is, adolescents who are more advanced in pubertal development were more likely to have had intercourse. Follow up moderation analyses revealed that this link was weaker for samples with a higher percentage of Black adolescents.

Combined sexual behavior. With a meta-analysis on 13 effect sizes, we found a moderate to large positive association between pubertal status and combined sexual behavior ($ESr=.42$). Adolescents who are more advanced in pubertal development were more likely to be engaged in sexual behavior. Moderation analyses indicated that this link was much stronger for girls compared to boys, and compared to mixed-sex samples. Further, this link was stronger for younger samples. There was no moderation by type of combined sexual behavior (coital or non-coital).

Pubertal Timing and Sexual Behavior and Risky Sexual Behavior

Sexual intercourse. With a meta-analysis on 19 effect sizes, we found a small positive association between pubertal timing and sexual intercourse status ($ESr=.14$). Adolescents with an early pubertal timing were more likely to be engaged in sexual intercourse. Moderation analyses

revealed that this link was much stronger for girls compared to boys, and much stronger for mixed-sex samples compared to boys. Further, this link was somewhat stronger for studies that used a stage-normative pubertal timing measure compared to a peer-normative pubertal timing measure, although this difference is small.

With a meta-analysis on 7 effect sizes, we found a small to moderate positive association between pubertal timing and age at sexual intercourse ($ESr=.21$). Adolescents with an early pubertal timing engaged in sexual intercourse at a younger age. This link was stronger for older adolescents, but there was no moderation by pubertal timing measure (peer-normative vs. stage-normative).

Combined sexual behavior. With a meta-analysis on 19 effect sizes, we found a small positive association between pubertal timing and combined sexual behavior status ($ESr=.14$). Adolescents with an early pubertal timing were more likely to be engaged in sexual behavior. Moderation analyses revealed that this link was much stronger for girls compared to mixed-sex samples, and stronger for older adolescents. There was no moderation by type of combined sexual behavior (coital vs. non-coital) and no moderation by pubertal timing measure (peer-normative vs. stage-normative).

With a meta-analysis on 7 effect sizes, we found a significant small positive association between pubertal timing and age at first sexual behavior ($ESr=.13$; no heterogeneity of effect sizes). That is, adolescents with an early pubertal timing were more likely to engage in their first sexual experience at a younger age.

Risky sexual behavior. With a meta-analysis on 12 effect sizes, we found a small positive association between pubertal timing and risky sexual behavior status ($ESr=.16$). Adolescents with an early pubertal timing engaged in more risky sexual behavior. This link was much stronger for girls compared to boys, and much stronger for girls compared to mixed-sex samples. This link was also stronger for younger adolescents, and much stronger when a peer-normative pubertal timing measure was used, compared to when objective stage-normative pubertal timing measure was used.

Age at Menarche and Sexual Behavior and Risky Sexual Behavior

Sexual intercourse. With a meta-analysis on 13 effect sizes, we found a small to moderate positive association between age at menarche and age at sexual intercourse ($ESr=.21$). Adolescents with a younger age at menarche engaged in sexual intercourse at a younger age. Moderation analyses revealed that this link was stronger for younger adolescents, and for samples with a higher percentage of Black adolescents.

There were only 5 effect sizes that examined the link between age at menarche and sexual intercourse status. We found a small positive association that showed that adolescents with a younger age at menarche were more likely to have engaged in sexual intercourse ($ESr=.15$). This link was stronger for younger adolescents. Of these five studies, three did not report ethnicity of the sample, and two examined the link between age at menarche and sexual intercourse status separately for Latina and Hispanic girls. The mean effect size of these latter two studies separately also showed a small positive association ($ESr=.07$, 95% CI [.04, .12], $p<.001$).

Combined sexual behavior. Only 4 effect sizes examined the link between age at menarche and combined sexual behavior—these showed a significant small positive association ($ESr=.10$; no heterogeneity of effect sizes). Adolescents with a younger age at menarche were more likely to engage in combined sexual behavior.

Risky sexual behavior. Only 6 effect sizes examined the link between age at menarche and risky sexual behavior. We found a large positive association that showed that adolescents with a younger age at menarche were more likely to engage in risky sexual behavior ($ESr=.51$). This link was stronger for younger adolescents.

Discussion

With the current study, we show the first meta-analytical results of the relation between pubertal development and adolescent sexual behavior. Our results indicated that those adolescents with an early pubertal timing engaged in earlier, more advanced, and more risky sexual behavior.

Also, those adolescents with a more advanced pubertal status engaged in earlier and more advanced sexual behavior.

Moderation of the Relation between Puberty and (Risky) Sexual Behavior

The current meta-analysis showed that the links of pubertal status and timing with non-risky and risky sexual behavior were more pronounced in girls. The effect of pubertal status on combined sexual behavior showed a strong effect for girls, but only a moderate effect for boys. The effect of pubertal timing on risky sexual behavior was moderate for girls, and only small for boys. This suggests a different mechanism by which puberty is related to sexual development for boys and girls.

Overall, the results showed that especially among young participants, (risky) sexual behavior was affected by a more advanced pubertal status, earlier pubertal timing, and a younger age at menarche. This may be because young adolescents are not as capable to handle potentially risky situations [68] or because they have of a delay in the development of the cognitive control system of the brain [69-70]. In contrast, older adolescents are thought to have more opportunities to engage in sexual behavior, possibly because they experience fewer parental restrictions [71,72].

Moderation by ethnicity showed inconsistent findings. For pubertal status measures that reflect thelarche, adrenarche, and gonadarche, stronger links for White adolescents are found, whereas for the later-occurring menarche stronger effects for Black girls are found. The difference between pubertal status and age at menarche is important to consider because this indicates that pubertal status may show a combined effect of the development of several secondary sex characteristics, whereas menarche is the final stage of girls' pubertal development and an indicator of gonadarche. The current findings indicate ethnic differences in the magnitude of the link between pubertal development and sexual development, but especially, that research needs to disentangle the effects of thelarche, adrenarche, and gonadarche, and how these processes during adolescence may affect ethnic groups differently.

Finally, we examined whether including a stage-normative or peer-normative measure of pubertal timing moderated the links between pubertal timing and sexual behavior and sexual risk behavior. For the link between pubertal timing and sexual intercourse status, we found a small difference—the effect of pubertal timing on sexual intercourse status was stronger when a stage-normative measure of pubertal timing was used. In contrast, for the link between pubertal timing and risky sexual behavior, we found a larger difference, and here the effect was stronger when a peer-normative measure was used. Our findings suggest that in predicting sexual risk behavior, the perception of one's pubertal timing may be even more important than the assessment of certain physical characteristics. This may indicate that when adolescents *perceive* their own pubertal development as “early” relative to peers, they will also be psychologically geared toward more older, and/or more deviant social contexts [73], or make them more vulnerable to the influences of such contexts (contextual amplification; [68]), thereby increasing their chances of engaging in sexual risk behavior. Given that very few studies include both peer-normative and stage-normative perceptions of pubertal timing in the same study, it is impossible to tease apart whether peer-normative puberty overrides stage-normative pubertal timing in predicting sexual behavior or whether two different mechanisms are operating: a biological mechanism that promotes sexual debut and a psychological one that promotes behavioral risk.

Pubertal Status versus Pubertal Timing

Three issues arise when comparing pubertal status to pubertal timing measures. First, several studies use a pubertal status measure in a sample of same-aged adolescents. Empirically speaking, if pubertal status is assessed in such a sample, this automatically reflects pubertal timing. Fortunately, we were able to account for this in the current meta-analysis by categorizing such studies as pubertal timing. However, it is clear that even among researchers, the distinction between pubertal status and pubertal timing is not always evident and, in addition to the assessment measure used, also depends on other factors. These include the age of the participants in the study, whether pubertal status scores are standardized, and whether age is controlled for in the analyses. Second,

pubertal status and timing are confounded—those with an earlier pubertal timing have moved through more stages of pubertal development (which would indicate a more advanced pubertal status). In contrast, those with a later pubertal timing have not moved through as many stages and are thus categorized as having a less advanced pubertal status. Considering these confounds, it is difficult to interpret unique effects of pubertal status and timing, from general age-related changes [74]. Third, studies on pubertal development often combine several physical changes (such as pubic hair and breast development, or pubic hair and growth spurt) into one pubertal status or timing measure, regardless of their biological basis [75]. In sum, with this meta-analysis it becomes clear that the only way to distinguish pubertal status from timing is with a longitudinal study, accounting for individual differences in status, timing, and rate of development [76].

Strengths and Limitations

With the current meta-analysis, we were able to quantify the effects of pubertal development on sexual behavior and sexual risk behavior with a large number of participants and across a wide range of ages. Although we were able to identify many gaps in the literature and provide a quantitative meta-analysis on the relation between pubertal development and sexual behavior, there are several limitations to this meta-analysis and the studies included to note. First, the measurement of pubertal development and sexual behavior was primarily by self-report and some were retrospective, which can be biased [5,77]. Second, we categorized studies based on what they reported in the papers as their measures. Unfortunately, many studies do not clearly report the pubertal development measure, nor do many studies report whether they controlled for sex or age in their measure or analyses. In addition to these methodological limitations to the studies, the current meta-analysis is limited in its conclusions about ethnicity. We were unable to include moderation by ethnicity other than percentage of Black participants. Such a measure gets at an indirect measure of whether the link between pubertal development varies when more or less members of an ethnic group are included in the sample, but the magnitude of the actual relation between pubertal development and sexual behavior cannot be estimated. Our meta-analysis underscores two points:

(1) the need for investigators to report their analyses separately by ethnic group when ethnic minorities are included in their report, and (2) more research on pubertal and sexual development among different ethnic groups is needed and over-sampling of these groups within stratification samples may be necessary to achieve sufficient power and reliability of the results.

Future Research and Implications

The current meta-analysis suggests that puberty affects boys and girls differently, or that the environment reacts differently to their physical changes. In order to extend these findings even further, both for girls and boys, studies need to incorporate the social context into their research. Pubertal and sexual development do not occur in a vacuum—reactions from peers concerning the adolescents' changing body, the relational context of sexual behavior, and availability of sexual health care all interact to affect adolescent sexuality. Further, our findings on sexual risk behavior among early maturing adolescents—strengthened by the idea that when adolescents engage in sexual behavior at young ages they tend to engage in more risky behaviors [78]—emphasize the need for early interventions to prevent pregnancy and STIs/HIV.

Conclusion

Our findings underline the important role of an early transition to reproductive maturity for the onset and timing of sexual and risky sexual behavior that is stronger for girls than for boys. In order to study adolescent sexual development with a developmental systems approach, hormonal, genetic, and environmental factors need to be included.

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Footnotes

¹ Results of the random effects models are available from the corresponding author upon request.

Table 1

Included Studies and Characteristics

	Puberty measure	Sexual behavior measure	Sex of sample	Mean age	Country	Ethnicity	N	r
Sexual intercourse								
(1) Arim et al., 2011 [22]	Pubertal timing relative to peers based on PDS	Intercourse status	(1) Boys	13	Canada	--	3700	0.03
(2) Benson et al., 1995 [23]	Timing of age at menarche or first semen release	Virginity loss (yes/no)	(2) Girls 50% Boys; 50% Girls	13	USA	33% Black 45% Hispanic 27% White	3564 307	0.27 0.32
Bingham et al., 1990 [24]	Age at menarche	Age at first sexual intercourse	Girls	17	USA	--	1717	0.17
(1) Brown et al., 2006 [25]	Pubertal timing relative to peers	Sexual intercourse status (yes/no) at follow up (2 yrs later)	50% Boys; 50% Girls	13.7	USA	(1) 100% Black	526	0.13
(2)						(2) 100% White	491	0.06
Campbell et al., 2005 [26]	Pubertal status based on secondary sexual characteristics, first erection, and first spontaneous nocturnal emission	Intercourse status	Boys	15	Zimbabwe	100% Black	437	0.09
(1) Cavanagh, 2004 [13]	Age at menarche	Sexual intercourse status	Girls	13.88	USA	(1) 100% White	882	0.20
(2)					USA	(2) 100% Latina	149	0.40
(1) Crockett et al., 1996 [27]	Pubertal timing relative to peers of the same age and gender	Timing of first intercourse (early, middle, or late)	(1) Girls	16.5		--	166	0.06
(2) Deardorff et al., 2005 [28]	Age at menarche	Age at first sexual intercourse	(2) Boys Girls	20.5	USA	13.8% Black 31.4% Latina 28.7% Non-Hispanic white 23.9% Native	123 666	0.04 0.27

(1) Deppen et al., 2012 [29]	(1) Perception of pubertal timing (on-time vs. early) on time is reference group	Sexual intercourse before age 16	Girls	18	Switzerland	2.0% Other 18.1% parental non-Swiss origin	890	0.20
(2)	(2) Perception of pubertal timing (on-time vs. late) on time is reference group					17.4% parental non-Swiss origin	778	0.31
Durant et al., 1990 [21]	Age of menarche	Engaging in premarital coitus	Girls	17	USA	100% Hispanic	202	0.25
Edgardh, 2000 [30]	Menarche < 11 years, or 11 years	Coitarche < 15 years; Coitarche > 15 years	Girls	17	Sweden	--	712	0.21
Edgardh, 2002 [31]	Pubertal timing assessed with early puberty (first ejaculation before age 13)	Intercourse status	Boys	17	Sweden	13% Immigrant background	647	0.19
Felson & Haynie, 2002 [32]	Pubertal status assessed with PDS items on pubic hair; facial hair; and voice changes. Items were summed.	Sexual intercourse (yes/no)	Boys	14.1	USA	54% White	5700	0.20
Gaudineau et al., 2010 [33]	Early menarche (before 11yrs old)	Sexual intercourse before 15yrs old	Girls	15	France	--	1072	0.20
Johnson & Tyler, 2007 [34]	Pubertal status assessed with status question for boys and menarche onset question for girls	Age at first sexual intercourse	52% Boys; 48% Girls	12.59	USA	--	2494	0.11
Kahn et al., 2002 [35]	Age at menarche	Age at first sexual intercourse	Girls	20.4	USA	59% White 12% Black 13% Hispanic 9% Asian 7% other	504	0.16
(1) Khurana et al., 2012 [37]	Pubertal status assessed with Tanner drawings (boys: genitals and body hair; girls: breast and	(1) Intercourse status	48% Boys; 52% Girls	13.4	USA	55% Non-Hispanic White 28% Non-Hispanic Black	347	0.26

(2)	pubic hair)	(2) Intercourse status 1 yr later				9% Hispanic		0.26
Kim & Smith, 1999 [36]	Age at menarche	Age at first sexual intercourse	Girls	19.5	UK	--	228	0.34
Koo et al., 2012 [38]	Pubertal status (boys: questions about body and voice change; girls: questions about breast development and body hair).	Intercourse status	45.1% Boys; 54.9% Girls	10.5	USA	99% African American	408	0.26
(1) Kuzman et al., 2007 [39]	(1) Age at menarche; On time compared to early	Sexual intercourse before 16yrs old.	Girls	15.5	Croatia	--	656	0.19
(2)	(2) Age at menarche; Late compared to early						284	0.31
(1) Kvaalem et al., 2011 [40]	Pubertal timing relative to peers at wave 1	Coital onset at wave 2 (2 yrs later)	(1) Boys	14	Norway	--	1246	0.09
(2)			(2) Girls			--	1343	0.04
(3)	Pubertal timing relative to peers at wave 2	Coital onset at wave 3 (5 yrs later)	(3) Boys	15.6		--	598	0.03
(4)			(4) Girls			--	662	0.04
(1) Lam et al., 2002 [20]	(1) Age at first emission (first conscious ejaculation)	Sexual intercourse (yes/no)	Boys	16	Hongkong	--	1905	0.12
(2)	(2) Age at menarche		Girls				1907	0.06
(1) Meschke et al., 2000 [41]	(1) Age at menarche	Age at first sexual intercourse (< age 16; age 16+; inexperienced)	Girls	16.5	USA	100% White	268	0.28
(2)	(2) Age at growth spurt		Boys	16.5			157	0.12
(1) Michaud et al., 2006 [42]	(1) Pubertal timing relative to peers; Early vs average	Sexually active	Girls	18	Switzerland	--	2771	0.18
(2)	(2) Pubertal timing relative to peers; Late vs average						2314	0.13
(3)	(3) Pubertal timing relative to peers;		Boys				3359	0.16

(4)	Early vs on time (4) Pubertal timing; relative to peers; Late vs on time						3018	0.15
Miller et al., 1997 [43]	Age at menarche	Age at first sexual intercourse	Girls	20.5	USA	28.7% Black	386	0.06
Neberich et al., 2010 [44]	Age at menarche	Age at first sexual intercourse	Girls	21.4	Germany	--	381	0.17
(1) Ostovic & Sabini, 2005 [45]	Pubertal timing assessed with ages at several pubertal development events	Intercourse status	(1) Girls	21.8	USA	58.8% White 27% Asian or Asian-Indian 4.3% Black 3.2% Hispanic 6.7% Other	141	0.06
(2)			(2) Boys	22.4			124	0.12
Part et al., 2011 [46]	Pubertal timing assessed with ages at menarche and spermatarche	Intercourse status	46.9% Boys; 53.1% Girls	15.5	Estonia	--	959	0.17
(1) Phinney et al., 1990 [47]	Age at menarche	Age at first sexual intercourse	Girls	17	USA	(1) 100% Black	581	0.29
(2)						(2) 100% Non- black	1253	0.17
Rosenthal et al., 2001 [48]	Age at menarche	Age at initial sexual intercourse	Girls	14.5	USA	78% Black 22% White	143	0.66
(1) Rosenthal et al., 1999 [49]	Physical development timing (less or about as mature as peers vs. more mature than peers)	Timing of sexual intercourse (early or late initiator)	(1) Boys	16.6	Australia	--	94	0.20
(2)			(2) Girls				147	0.16
Spencer et al., 2002 [50]	Pubertal timing assessed with ages at several pubertal development events	Intercourse status	43% Boys; 57% Girls	12.5	USA	84% White 16% Black	188	0.14
Vanoss Marín et al., 2000 [51]	Menarcheal status	Sexual intercourse (yes/no)	Girls	11.5	USA		1242	0.19

Combined sexual behavior

(1) Brown et al., 2006 [25]	Pubertal timing relative to peers	Precoital sexual activity (kissing-oral sex) at follow up (2 yrs later)	50% Boys; 50% Girls	13.7	USA	(1) 100% Black	526	0.22
(2)						(2) 100% White	491	0.08
(1) Campbell et al., 2005 [24]	Pubertal status based on secondary sexual characteristics, first erection, and first spontaneous nocturnal emission	(1) Light petting	Boys	15	Zimbabwe	100% Black	397	0.19
(2)		(2) Heavy petting					414	0.12
(1) Flannery et al., 1993 [52]	Pubertal status (Tanner line drawings)	(1) Sexual experience (kissed-intercourse)	(1) Boys	13.5	USA	78% Caucasian parents 15% Hispanic parents	376	0.51
(2)			(2) Girls				397	0.53
(1) Hipwell et al., 2010 [53]	Onset of menarche at age 11 (yes/no)	(1) None vs moderate sexually intimate behavior At age 12	Girls	11.58	USA	54.8% African American 39% European American 6.2% multiethnic or belonging to another ethnic group	604	0.18
(2)		(2) Mild vs moderate sexually intimate behavior At age 12					581	0.08
(1) James et al., 2012 [8]	Pubertal maturation (combined measure incl PDS) at time 1 (grade 6). <i>Recoded as pubertal timing.^a</i>	Timing of sexual debut at time 7 (grade 12) Average of first sexual encounter, and first sexual intercourse.	Girls	11.86	USA	82% European American 14% African American 4% other	129	0.33
(2)			Boys	13.86			109	0.17
(1) Lam et al., 2002 [20]	Age at first emission	(1) Kissing	Boys	16	Hongkong	--	1912	0.11

(9)	(9) PDS at wave 1							0.08
(1) Ostovic & Sabini (2005) [45]	Pubertal timing assessed with ages at several pubertal development events	Age at first sexual arousal	(1) Girls	21.8	USA	58.8% White 27.0% Asian or Asian-Indian 4.3% Black 3.2% Hispanic; 6.7% Other	148	0.47
(2)			(2) Boys	22.4			129	0.46
(1) Price et al., 2009 [57]	Pubertal status at age 13 assessed with Tanner line drawings	Sexual behavior (oral and/or coital) at age 15	(1) Girls	13	USA	90% European American 4% African American 2% Asian American 2% Hispanic 2% Native American	127	0.15
(2)			(2) Boys				110	0.23
(1) Savin-Williams, 1995 [58]	Age at pubertal onset	(1) First homosexual sexual experience	Boys	20.9	USA	--	71	0.30
(2)		(2) First heterosexual sexual experience					41	0.07
(1) Smith et al., 1985 [59]	(1) Pubic hair stage assessed with Tanner drawing.	Sexual behavior (kissing-intercourse)	Girls	13.5	USA	100% White	433	0.93
(2)	(2) Estrogen development assessed with a Tanner drawing of breast development and three items assessing perception of breast and hip development, and general "curviness".							0.54
(3)	(3) Pubertal status measured by ten items		Boys				378	0.87
Van Ryzin (2011) [60]	Physical maturity	Sexual experimentation	52% Boys;	14	USA	88% Euro-	363	0.11

	assessed with two items on body hair and skin changes. <i>Recoded as pubertal timing.</i> ^a	(items on kissing – touching below the waist summed)	48% Girls			American 7% mixed ethnic background 2% Hispanic 1% African American 1% Native American 1% Asia American		
(1) Van Zalk et al., 2011 [61]	Pubertal status assessed with a partial PDS	(1) Lifetime intercourse frequency (no-several times) wave 1	52% Boys; 48% Girls	13.73	Sweden	13% 1 st born immigrant 12.5% 2 nd born immigrant	750	0.18
(2)		(2) Lifetime intercourse frequency (no-several times) wave 2						0.21
(3)		(3) Impulsive sexual behavior (sleeping on the first night) wave 1						0.14
(4)		(4) Impulsive sexual behavior (sleeping on the first night) wave 2						0.21
Risky sexual behavior								
Aruda, 2010 [62]	Age at menarche	Condom-use	Girls	18	USA	36% Hispanic & 50.2% Black 17% White 4% American indian 0.3% Asian 22% Other	305	0.56
Belsky et al., 2010 [63]	Age at menarche	Risky sexual behavior at age 15	Girls	12.5	USA	82% White 12% Black 6% Hispanic	526	0.25
(1) Boden et al., 2011 [64]	Age at menarche	(1) Pregnant by age 18	Girls	13.5	New Zealand	--	497	0.73
(2)		(2) One or more STI by						0.63

Durant et al., 1990 [21]	Age at menarche	age 18 Contraceptive behavior	Girls	17	USA	100% Hispanic	85	0.25
(1) Halpern et al., 2007 [65]	Pubertal timing relative to peers	Sex for drugs or money	(1) Boys	14.0	USA	79% White 14% Black 7% Other	1879	0.03
(2)			(2) Girls	13.9			2239	0.33
(3)		Combination sex and drug use	(3) Boys				1879	0.13
(4)			(4) Girls				2239	0.21
(1) James et al., 2012 [8]	(1) Pubertal timing at time 1 assessed with the PDS and IAD, partialling out age. <i>Recoded as pubertal timing.^a</i>	Risky sexual behavior 6 years later	Girls	11.86	USA	82% European American 14% African American 4% other	129	0.25
(2)	(2) Pubertal timing at time 3 assessed with the PDS and IAD, partialling out age	Risky sexual behavior 4 years later	Boys	13.56			109	0.02
(1) Marceau et al., 2011 [66]	(1) Tanner pubic hair	Risky sexual behavior	Boys	15.5	USA	100% White	326	0.03
(2)	(2) Tanner genital development						326	0.04
(3)	(3) Tanner pubic hair		Girls				340	0.05
(4)	(4) Tanner breast development						343	0.04
Shew et al., 1994 [67]	Age at menarche	HPV infection (yes/no)	Girls	17	USA	48% White 44% Black 7% Other	208	0.06
(1) Siebenbruner et al., 2007 [19]	Physical maturity rated by coders, at age 13. <i>Recoded as pubertal timing.^a</i>	(1) High risk versus sexual abstainers. Sexual risk behavior at age 16. Composed of number of sexual partners and contraception use.	54% Boys; 46% Girls	13	USA	Mother's ethnicity: 86% Caucasian 10% African American 4% Native American or Asian	118	0.04

(2)	(2) Low risk versus sexual abstainers. Sexual risk behavior at age 16. Composed of number of sexual partners and contraception use.	122 0.07
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Note. The included studies and study characteristics are presented in order of sexual behavior measure, and then in order of alphabet. The numbers in front of the author list represent multiple effect sizes from the same study. Puberty measure presents the pubertal timing or status measure used in the study, sexual behavior measure presents the measure that was used to assess sexual behavior or risky sexual behavior. Sex of sample includes 100% boys (Boys), 100% girls (Girls) or a mix of boys and girls, percentages are denoted. Mean age denotes the mean age of the sample included in the analyses, if the mean sample was not reported, the media age of the range was included in the analyses. Country denotes the country in which the study was conducted. Ethnicity denotes the reported percentages of adolescents with ethnic backgrounds. We included percentage of Black adolescents in the moderator analyses and the bold percentages represent the values included in the moderator analysis. *N* denotes the number of participants in the particular analysis. Recoded effect size denotes the recoded effect sizes to *r*. ^aThe effect sizes by James et al. (2012) and Van Ryzin (2011) were categorized under pubertal timing – age at combined sexual behavior because their pubertal status measure was assessed in a group of young adolescents with a narrow age-range. The effect sizes by Siebenbruner (2007) were categorized under pubertal timing – risky sexual behavior because their pubertal status measure was assessed in a sample of adolescents with the same age.

Table 2

Omnibus Q-statistics for the separate meta-analyses

	<i>N</i>	<i>Q omnibus</i>	<i>df</i>	<i>p</i>	<i>k</i>	<i>ES</i>	<i>95%CI</i>
Pubertal status							
Age at sexual intercourse ^a	2494	--	--	--	1	.11	--
Sexual intercourse status ^{ab}	1242	--	--	--	1	.19	--
Sexual intercourse status	7239	9.93	4	.042	5	.20	[.18, .22]
Combined sexual behavior	6065	1279.12	12	< .001	13	.42	[.39, .44]
Pubertal timing							
Age at sexual intercourse	2355	18.42	6	.005	7	.21	[.17, .25]
Sexual intercourse status	28050	163.19	18	< .001	19	.14	[.13, .15]
Age at combined sexual behavior	1303	9.24	6	.161	7	.13	[.08, .19]
Combined sexual behavior	9610	65.29	18	< .001	19	.14	[.12, .16]
Risky sexual behavior	10049	133.08	11	< .001	12	.16	[.14, .18]
Age at menarche							
Age at sexual intercourse	7779	79.21	12	< .001	13	.21	[.19, .23]
Sexual intercourse status	4212	31.99	4	< .001	5	.15	[.11, .18]
Combined sexual behavior	4982	4.37	3	.225	4	.10	[.08, .13]
Risky sexual behavior	2118	192.49	5	< .001	6	.51	[.48, .54]

^a We were unable to test heterogeneity of effect sizes because only one study could be included for this analysis. ^b This category includes the link of menarcheal status and sexual intercourse status, but has been categorized under pubertal status.

Table 3

Moderating Effects of Gender, Age, and Ethnicity for the Different Meta-Analyses

	Moderator						
	Sex			Age ^a	Ethn. ^b	PT ^c	Coital ^d
	Boys (0) vs. Girls (1)	Mixed (0) vs. Girls (1)	Boys (0) vs. Mixed(1)				
Pubertal status							
Age at sexual intercourse ^e	--	--	--	--	--	--	--
Sexual intercourse status ^{ef}	--	--	--	--	--	--	--
Sexual intercourse status	--	--	ns	ns	-.71*	--	--
Combined sexual behavior	.35***	.73***	-.49***	-.35***	--	--	ns
Pubertal timing							
Age at sexual intercourse	ns	--	--	.76***	--	ns	--
Sexual intercourse status	.40***	ns	.26*	ns	ns	.33**	--
						*	
Age at combined sexual behavior ^g	--	--	--	--	--	--	--
Combined sexual behavior	.39*	.42**	ns	.25*	ns	ns	ns
Risky sexual behavior	.70***	.60***	ns	-.40***	--	-.29*	--
Age at menarche							
Age at sexual intercourse	--	--	--	-.27*	.38**	--	--
Sexual intercourse status	--	--	--	-.63***	--	--	--
Combined sexual behavior ^g	--	--	--	--	--	--	--
Risky sexual behavior	--	--	--	-.15*	--	--	--

Note. ns = not-significant, $p > .05$. * $< .05$ ** $< .01$ *** $< .001$. Dashes represent moderator analyses that could not be tested due to lack of variance or non-report of moderator. Ethn. = ethnicity. PT = Pubertal timing measure. Coital = combined sexual behavior measure includes coital or does not include coital behaviors. ^a Positive values indicate stronger relations for older youth. Negative values indicate stronger relations for younger youth. ^b Positive values indicate stronger relations for samples with a higher percentage of Black adolescents. Negative values indicate stronger

relations for samples with a lower percentage of Black adolescents. ^c 0 = peer-normative pubertal timing, 1 = stage-normative pubertal timing. ^d 0 = exclusively non-coital, 1 = coital. ^e We were unable to test moderation effects because only one study could be included for this analysis. ^f This category includes the link of menarcheal status and sexual intercourse status, but has been categorized under pubertal status. ^g We were unable to test moderator effects because there was no heterogeneity in effect sizes.

Table 4

Effects Sizes and Confidence Intervals for Significant Categorical Moderators

	Moderator				
	Sex			PT ^a	
	Boys	Girls	Mixed	Peer- normative	Stage- normative
Pubertal status					
Combined sexual behavior	.48 [.44, .51]	.72 [.69, .74]	.19 [.15, .22]	--	--
Pubertal timing					
Sexual intercourse status	.11 [.09, .13]	.17 [.15, .19]	.16 [.12, .20]	.13 [.11, .14]	.15 [.13, .17]
Combined sexual behavior	.13 [.10- .16]-	.29 [.19, .40]	.15 [.12, .17]	--	--
Risky sexual behavior	.07 [.04, .10]	.24 [.21, .26]	.05 [-.07, .18]	.18 [.16, .20]	.06 [.01, .10]

Note. Dashes represent moderator analyses that could not be tested due to lack of variance or non-report of moderator, or where differences were not significant. PT = Pubertal timing measure.