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Review Article

Vulvar Developmental Stages During Puberty: A Systematic Review

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ABSTRACT

Study Objective: Puberty is associated with important changes in secondary sexual characteristics, but the changes occurring in female external genitalia are not thoroughly described. The aim of this systematic review is to summarize and assess the current scientific knowledge regarding vulvar changes and development during puberty.
Methods: PubMed, Embase, Web of Science, and Cochrane were searched using keywords related to "puberty," "vulva," and "morphology." The inclusion criteria were observational studies describing vulvar development in individuals between the ages of 8 and 16 years. The outcomes of interest were quantitative and/or qualitative descriptions of the vulva, including anatomic, physiological, and histological changes.
Results: Of the 1658 articles screened, 10 were included. The mean clitoral glans diameter increases during puberty, as does the length of the clitoral hood. The clitoral hood changes to become more retractile and rugose. The inner labia width and length increase throughout puberty, and the development of the inner labia varies between individuals, with labial asymmetry being a common characteristic. The most frequent hymenal configuration found during puberty is the crescentic form, and features such as hymenal mounds, longitudinal intravaginal ridges, and most notches are physiological.
Conclusion: Reliable data on pubertal development of the external female genital organs are scarce. Future research is needed to provide more precise data to help categorize vulvar development into stages. A detailed description of vulvar maturation into sequential stages throughout puberty (as done by the Tanner scale for the male homologous structures) can increase knowledge of its morphologic diversity and help reach clinical consensus on the nature of pathologic variants. In addition, better knowledge of vulvar diversity is important to both health care professionals and individuals and may empower and promote self-esteem.
Key Words: (Genitalia, female), Vulva, Hymen, Clitoris, Puberty, Sexual development, Sex characteristics, Growth & development, Anatomy

Introduction

Puberty induces important anatomic and functional changes in secondary sexual characteristics and external genital organs. This development is partially described using the Tanner scale, which was developed by British pediatric endocrinologist James M Tanner and first published in 1955.[1] In individuals with a penis, the Tanner scale describes development of pubic hair and changes in genitalia, including the enlargement of the testes, penis, and scrotum. In girls, the stages describe pubic hair growth and distribution and breast development.[1,2] Tanner stages do not include changes in ovarian size, clitoris, inner and outer labia size, and color. Despite its wide use, the Tanner scale lacks an accurate description of vulvar anatomy and its modification during puberty. To this day, there are surprisingly few descriptions of vulvar maturation during puberty and largely insufficient detail to categorize this development into stages.[3,4]

Such a lack of data is not without consequences for individuals born with a vulva and for health care professionals (HCPs). Studies show an increase in requests for female genital cosmetic surgery among adolescents and young adults. For example, labiaplasty numbers in the National Health Service in the United Kingdom increased fivefold between 2001 and 2010,[5] and similarly, in Australia, demands more than doubled over the same period.[6] Several studies have shown that the most frequently reported reason for surgery is an aesthetic concern.[7] The increasing demand for female genital cosmetic surgery is an indirect indicator of increasing genital dissatisfaction[8]; this could be a sociocultural consequence of increased media and pornography exposure, which largely portray adult vulvas without hair and with small inner labia, resembling prepubertal genitals.[7,9] In a study of 21 young women, all subjects identified the hairless genitalia with no visible inner labia as the "socially accepted ideal" vulva.[10] The widespread portrayal of these "prepubertal-like vulvas" in mass-media is particularly deleterious among young adolescents, who use the Internet as an important or sole source for sexual education and information.[11] Furthermore, adolescence is a particularly vulnerable period in terms of self-esteem construction. The comparison of one's body with images portrayed in the media can have a significant impact on psychological and physiological well-being. This unrealistic

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genital image is far from the diversity of existing physiologic vulvar appearances.

Therefore, a detailed comprehension and description of morphologic vulvar changes during puberty is necessary for both HCPs and patients to better describe physiological development, providing reassurance regarding physiologic variants and enabling better identification of any potentially pathologic conditions.

The objective of this systematic review is to provide an overview of the current scientific knowledge regarding vulvar changes and development during puberty, including morphologic, histologic, and physiological changes.

Methods

We conducted a systematic review using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement, which can be found in the Supporting Information, and Muka et al's guidelines.[12] Medline (through PubMed), Embase, Web of Science, and Cochrane were searched in June 2023, using language filters for English, French, Italian, and Spanish and without any time restriction. The protocol was registered in PROSPERO (study ID: CRD42023443266). The search strategy is detailed in the Supporting Information.

Study eligibility was determined using the PICO framework.[13] Observational studies describing the vulvas of individuals between the ages of 8 and 16 years old were included. This age range was chosen because puberty onset is defined by thelarche, which usually appears between the ages of 8 and 13.[14] Menarche is the last stage of puberty and starts on average 2-3 years after thelarche,[14] therefore marking the end of the included age range at 16 years. Studies including participants outside the age range but providing distinct data for the age category of 8-16 years were included. The outcomes of interest were quantitative and/or qualitative descriptions of the vulva, including anatomic, physiological, and/or histologic changes during puberty. Articles were excluded if they only described unhealthy vulvar conditions or traumatisms or if the population included individuals with precocious or delayed puberty, variations in sex development, or exposure to sexual abuse. Articles reporting nonoriginal research and book chapters were excluded.

Duplicate records were eliminated using the Bramer method with EndNote[15] and using Rayyan's deduplication software. Titles and abstracts were then screened by two independent reviewers (FC and CB) using Rayyan software, and any disagreements were resolved between the two authors. The full texts of selected studies were screened by FC and a second independent reviewer (DM or VC). Any discrepancies between the reviewers were resolved by consensus or by a third reviewer (MY) if no consensus was reached. Excluded articles were labelled with a reason from the following list: wrong study design, wrong population, wrong outcome, or wrong exposure.

Data including author, year published, study design, country, recruitment period, number of subjects, age range, and outcomes were extracted by FC and included in a summary diagram (Table 1). The methodological quality of the included studies was assessed independently by 2 authors (FC and DM) using the Johanna Briggs Institute (JBI) critical appraisal tools,[16] and disagreements were resolved by consensus. A raw score was calculated for each of the selected studies by dividing the number of "Yes" responses by the total number of applicable statements in the JBI critical appraisal tools. High risk of bias was defined as a raw score of 49% or lower, moderate risk of bias was defined as raw score between 50% and 69%, and low risk of bias was defined as a raw score of 70% or above.[17]

Due to important differences in the methodologies and outcomes for the included articles, the results were synthesized using a narrative approach.

Results

Study Selection

A total of 1658 studies were identified for screening after removal of duplicate articles. After abstract review, 105 reports were sought for full-text retrieval. Following full-text review and resolution of disagreements, 10 articles met the inclusion criteria (see Fig. 1[18]), of which 4 were cohort studies,[19-22] 4 were cross-sectional studies,[23-26] and 2 were case series,[11,27] involving a total of 349 subjects.

Characteristics of Studies and Participants

The included studies were published between 1991 and 2023. Five studies were conducted in North America and one in each of the following countries: Australia, Greece, Turkey, China, and Norway. The number of participants varied from 4 patients in Boulos et al's case series[27] to 152 in Biro et al's cohort study.[20]

Descriptions of ethnicity were limited. Five articles did not specify the ethnicity of the included subjects[11,22,25-27]; three articles included only White participants[20,21,24]; one article included Black non-Hispanic, White non-Hispanic, and Hispanic participants[19]; and one article included White non-Hispanic, White Hispanic, African-American, Mixed Hispanic, and Native American participants.[23]

Studies were divided according to which vulvar structure they analyzed. Four articles discussed changes in hymenal morphology,[19,21,24,25] four focused on the inner labia,[11,22,23,27] two focused on the clitoris,[23,26] one focused on pubic hair maturation,[20] and one focused on the overall vulvar measurements.[23]

Pubic Hair Maturation

A longitudinal study evaluating the initial manifestations of puberty recruited 443 subjects at 9 or 10 years of age and followed them annually for 10 years.[20] Participants were classified as following either the thelarche or adrenarche pathway, depending on whether the first manifestation of puberty was areolar maturation or pubic hair, respectively. A third of the participants (152/443, 34.3%) had adrenarche as the initial manifestation of puberty, and the mean age of onset was 10.7 ± 0.9 years. In the year after the onset of puberty, 78% of participants in the adrenarche

Table 1
Summary of Characteristics and Key Results of Included Studies

Author	Year	Study design	Study country	Recruitment period	No. of subjects	Age of subjects (years)	Ethnicity (and % of participants in each category)	Measuring position	Primary outcomes	Key results
Berenson et al[19]	2002	Cohort	USA	Not described	61	9	Black, non-Hispanic (51%), White, non-Hispanic (26%), Hispanic (23%)	Supine with labial traction and knee-chest	Hymen	90% of participants had a crescentic hymenal configuration. Mean horizontal and vertical trans-hymenal diameter increased as the sample aged ($P < .01$). Hymenal features, such as periurethral band and longitudinal intravaginal ridges, were very common, with a 100% and 92% prevalence, respectively.
Biro et al[20]	2003	Cohort	USA	Not described	152	9-10	White (100%)	Not described	Pubic hair maturation	Mean age (± SD) for onset of puberty among participants in adrenarche pathway = 10.7 ± 0.9. In the year after puberty onset, 78% of subjects in adrenarche pathway advanced in areolar maturation and 37% advanced in pubic hair maturation ($P < .001$)
Boulos et al[27]	2018	Case series	USA	Not described	4	11-13	Not described	Not described	Inner labia	Hypertrophy of inner labia is a variant of normal anatomy. Typical histologic features of inner labial hypertrophy include papillomatosis, sebaceous gland hyperplasia, dilated and increased lymphatic vessels, a fibrous stroma, and features of lichen simplex chronicus.
Brodie et al[23]	2016	Cross-sectional	USA	Sept. 2014-May 2015	22	9-16	White non-Hispanic, White Hispanic, African American, Mixed Hispanic, Native American (% of each category not available)	Lithotomy	Glans, inner labia, overall vulvar structure	All genitalia measurements increased with age, but with large variation between subjects. Clitoral hood to urethral orifice distance and inner labia length and width showed steep growth during puberty. The tent shape is the most common clitoral hood shape.
Gardner[24]	1992	Cross-sectional	Australia	April 1988-March 1989	9	10-11	White (100%)	Not described	Hymen	Posterior rim (or crescentic hymen) was the most common configuration.
Michala et al[11]	2011	Case series	Greece	June 2009-December 2010	12	10-16	Not described	Not described	Inner labia	Average inner labia width (mm) = 35.6 (range 20-55 mm). 9 of 12 participants had asymmetrical inner labia, with an average difference of 15.22 mm between right and left inner labia.
Myhre et al[21]	2010	Cohort	Norway	April-September 2005	31	10-13	White (100%)	Supine	Hymen	Crescentic hymen was the most common configuration. Increase in hymenal thickness and redundancy at follow-up examination ($P = .000$), with a tendency of folding out and developing hymenal groove. Increase in horizontal hymenal diameter.
Onderoglu et al[25]	1992	Cross-sectional	Turkey	Not described	29	10-16	Not described	Lithotomy	Hymen	A fimbriated hymenal configuration is the most common, and its rate increases during puberty compared with prepubertal years.
Sane et al[26]	1991	Cross-sectional	USA	Not described	18	8-13	Not described	Frog-leg	Glans	Average clitoral index (mm^2 ± SEM) = 16.7 ± 0.9. Clitoral index increased during puberty, and is correlated with breast Tanner stage ($P = .001$), pubic hair Tanner stage ($P < .002$), and body surface area ($P < .001$)
Qin et al[22]	2023	Cohort	China	January 2016- May 2022	11	9-16	Not described	Not described	Inner labia	8 of 11 participants had asymmetrical inner labia.

pathway had advanced in areolar maturation, and 37% had advanced in pubic hair maturation.

Clitoris Glans and Clitoral Hood

Brodie et al report an increase in the mean length of the clitoral hood, length of the sides of the clitoral hood, and mean clitoral diameter between groups of subjects aged 9-12 and 13-16 in a cross-sectional study.[23] Details on how each measurement was taken can be found in the original article. The mean clitoral diameter and mean length of the clitoral hood increased by an average of 0.6 and 4.0 mm, respectively. They also reported four shapes of clitoral hoods: horseshoe, trumpet, coffee bean, and tent. The tent shape, with the clitoral hood dividing into right and left leaflets to provide a central opening for the glans, was the most common in both groups. As age increased, the clitoral hood exhibited greater retractility and rugosity. Across both age categories, the clitoral hood and inner labia generally formed 2 distinct structures, with the upper extremities

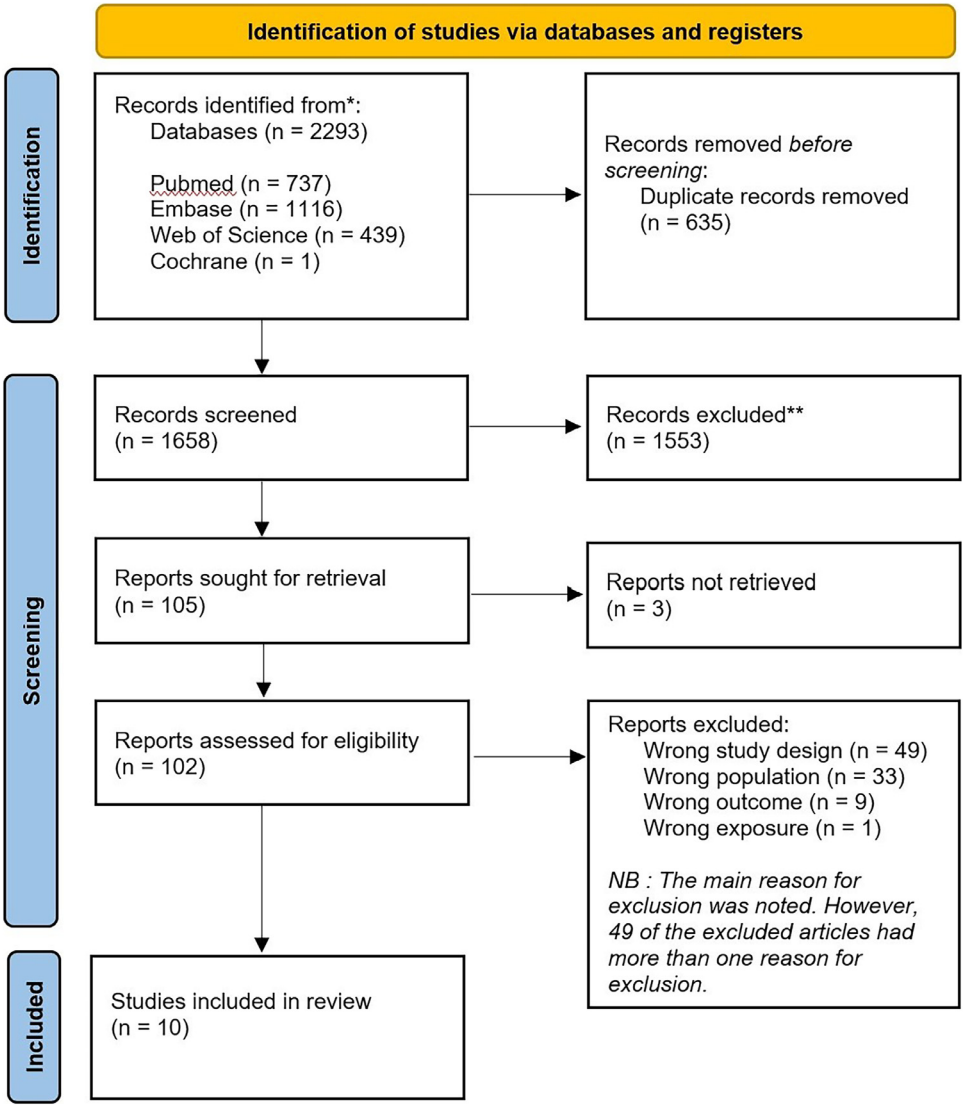

Fig. 1. Flow chart for included articles, following the PRISMA 2020 flow diagram guidelines.[27]

of the inner labia connecting under the glans to form the frenulum of the clitoris.

Another study reported the clitoral index,[26] or glans' surface area, calculated as a product of the longest sagittal and transverse lengths of the glans, in millimeters squared. The authors found an average of 16.7 ± 0.9 mm^2 for subjects in the 8-13 years category. This index was increased compared with the prepubertal age groups and was also correlated with breast Tanner stage ($P = .001$), pubic hair Tanner stage ($P < .002$), and body surface area ($P < .001$).[26]

Inner Labia

Similarly to clitoral measurements, Brodie et al reported an increase in the inner labia length and width with age[23] in their cross-sectional study. The inner labia length was measured from the clitoral frenulum to the posterior fourchette, and the width was measured from the interlabial sulcus to the unstretched labial edges. Between the age groups of 9-12 and 13-16, there was an average of 163% increase in length and a 212% increase in the width of the inner labia. There was some variability of measurements, even among the same age categories. For example, in patients 9-12 years old, the range of the inner labia length was from 6 to 90 mm (average = 15.2 mm), and the width ranged from 1 to 15 mm (average = 3.9 mm). In subjects from 13 to 16 years old, the range of length was 20-80 mm (average = 40.0 mm), and the range of width was 3-17 mm (average = 12.2 mm), indicating a substantial overlap between age groups.[23] Michala et al measured the labial width from the hymenal ring to the edge of the labium in traction, in patients aged 10-16, and reported a range of width between 20 and 55 mm (average = 35.6 mm).[11]

Asymmetry in labial size was noted in several studies. In 8 of 11 patients aged 9-16 undergoing labiaplasty, Qin et al found asymmetrical inner labia before surgery.[22] Similarly, Michala et al observed asymmetry in 9 of 12 patients seeking assessment of their genitalia, with asymmetry ranging from 6 to 35 mm.[11]

Histologic features of the inner labia in four patients aged 11-13 presenting with unilateral inner labia hypertro-

phy were described in Boulos et al's 2018 article, revealing papillomatosis, sebaceous gland hyperplasia, dilated and increased lymphatic vessels, a fibrous stroma, and features of lichen simplex chronicus.[27]

Hymen

Four of the included articles analyzed hymenal configuration and descriptions. A cross-sectional study conducted in nine girls between the ages of 10 and 11 years old reported hymenal configuration, texture, irregularities, and vascularity.[24] The most frequent hymenal configuration found was a crescentic type (6/9, 67%), with annular (1/9, 11%), fimbriate (1/9, 11%), and remnant (1/9, 11%) configurations also observed. The crescentic (or posterior rim type) is characterized by an arc-shaped band of tissue in the inferior segment. The fimbriate hymen has an abundance of tissue surrounding the vaginal introitus, and the annular configuration has a circumferential opening.[28] Hymenal irregularities (such as bumps and notches) were not noted, although one case of asymmetric hymen was described. Hymenal vascularity amongst this age group was mostly classified as either "lacy," with delicate capillary beds, or increased, if thicker capillaries were noted. Features of the posterior fourchette also demonstrated significant variability, including an increased vascularity, a ragged surface (if the epithelial surface seemed irregular), notches, and midline sparing, and others were featureless (if the epithelium was intact and smooth).[24]

A longitudinal study analyzing hymenal development from ages 3 to 9 showed similar results.[19] Hymenal crescentic configuration was by far the most common at 9 years of age (54/60, 90%), and the proportion of crescentic configuration seemed to increase with age, whereas the annular hymen became less common with age ($P < .01$). Most subjects had at least one longitudinal intravaginal ridge (56/61, 92%), and this proportion was seen most frequently at the age of 9 ($P < .01$). The presence of at least one mound also tended to increase with age ($P < .01$). The number of notches, indentations found in the edge of the hymenal tissue, did not vary significantly over the different examinations. Mean horizontal and vertical trans-hymenal diameters also increased with age ($P < .01$). In patients with an annular hymen, the mean vertical diameter was 10.9 mm, and the average horizontal diameter was 6.1 mm, in the supine position. Both measurements showed variability, with ranges from 4.25 to 17.25 mm for vertical diameter and 1.75 to 12.25 mm for horizontal diameter. Participants were divided into three ethnic groups (Black non-Hispanic, White non-Hispanic, and Hispanic). Mounds were more frequently observed in Black non-Hispanic participants, whereas notches were more common in Black non-Hispanic and Hispanic patients.[19]

In contrast to Gardner et al's conclusion that fimbriated hymens were associated with infancy,[24] a cross-sectional study of 29 participants aged 10-16 reported that the fimbriate hymen was the most common configuration.[25] Specifically, 41% had a fimbriate hymen, whereas the majority of other subjects had annular or semilunar configurations.[25]

In Myhre et al's cohort study, hymenal configuration and features were compared in subjects of 5-7 years old and 11-13 years old.[21] During the follow-up visits, they found the hymen to thicken ($P = .000$) and an outward folding of the hymenal membrane to be more common. The presence of a fossa groove, an indentation in the mucosal membrane of the fossa navicularis, was only present at follow-up ($P = .02$). An increase in the horizontal hymenal diameter ($P = .011$) was noted, with an average of 5.13 mm for subjects between 11 and 13 years. When comparing prepubertal (Tanner stages B1/P1, B2/P1, or B1P2) and pubertal (Tanner stages B2/P2 or above) subjects, they found the crescentic configuration to be more common among prepubertal girls ($P = .063$).[21]

Overall Vulvar Measurements

Brodie et al's study analyzed changes in overall vulvar dimensions during puberty. They measured the distance from the apex of the clitoral hood to the urethral orifice, the clitoral hood to the lower border of the pubic symphysis, and the clitoral hood to the outer labia in millimeters. All three measurements increased between the ages of 9-12 and 13-16, with the clitoral hood to urethral orifice distance showing the steepest growth, from an average of 24.8 to 39.4 mm.[23]

Critical Appraisal of Methodology

Of the 10 studies included in this review, two were categorized as having a low risk of bias, two as having a moderate risk of bias, and six as having a high risk of bias. The details and raw scores of these studies are provided in the Supporting Information.

Discussion

To our current knowledge, this is the first systematic review aimed at exploring detailed morphologic vulvar changes during puberty. Despite limited information, we know that sexual hormones promote dermal deposition of adipose tissue in the outer labia and mons pubis and can change pigmentation and rugosity while increasing the size of other vulvar structures, such as the glans, inner labia, and vestibule.[3,29]

In this systematic review, we found that the glans of the clitoris and the length of the clitoral hood increase in size throughout puberty. Additionally, the clitoral hood becomes more retractile and develops more superficial rugae.[23]

Studies regarding the inner labia showed that the inner labia length and width increased in size between the ages of 9 and 16.[23] The studies also highlight the wide range of measurements that exist, and some report asymmetrical inner labia widths,[11,22] although there was no attempt to quantify the prevalence of asymmetric labia within a pubertal population. Interestingly, we know that the inner labia, which are rudimentary during childhood and appear to extend from the clitoral hood to approximately one-third the length of the outer labia, develop during puberty and eventually form a completely distinct layer

to join at the posterior commissure years after menarche.[29] This, however, was not discussed or noted in any of the articles evaluating changes in the labia minora. Moreover, no studies were found on changes that occur in the outer labia, vestibule, and mons pubis using our search criteria.

In three of four articles discussing hymenal morphology,[19,21,24] the crescentic configuration was the most common among subjects in early puberty and increased proportionally with age, probably due to effects of estrogen leading to dynamic changes such as increased thickness, with an outward folding of the hymenal membrane.[21] In prepubertal girls, the hymen is thinner, dry, and smooth-edged due to the suppression of the hypothalamic-pituitary-gonadal axis.[30] During puberty, the surrounding epithelial tissue increases in thickness and often appears less erythematous than before estrogenization.[31] The hymen itself can develop fimbriations, deep notches, tags, ridges, and rugae, which are often healthy anatomic variants,[29] as discussed in the included articles.

Despite these overall trends, one of the main findings of this systematic review is the high variability between subjects and the wide range of appearances and sizes of the vulva. This variability may be partially attributed to differences in study design and measuring standards but also to the inherent diversity of female external genital organs. This is important in clinical practice for HCPs and patients themselves. The vulva is often neglected during pre- and postgraduate medical training, and most general practitioners, gynecologists, and pediatricians are not familiar with differentiating physiological and pathologic findings.[32] In an Australian survey of 443 general practitioners, 97% of respondents had been asked by patients about genital "normality," and 65% had consulted with patients requesting referral for female genital cosmetic surgery. However, only 76% of general practitioners expressed confidence in assessing female genital anatomy.[33] Misconceptions and misunderstandings can lead to unjustified procedures such as labiaplasty and hymenoplasty, a controversial surgical procedure aimed at reducing the hymenal opening after vaginal penetration.[30,34] Despite the lack of scientific evidence to supporting the indications, standardization, and outcomes of these procedures, growing numbers of labiaplasty and hymenoplasty have been reported in industrialized countries.[5,6,35]

Reliable resources are important for HCPs in their daily practice and to provide reliable evidence-based information to their patients. In an analysis of 78 anatomic textbooks, Hayes et al did not find in textbooks published between 1848 and 2021 any references to vulvar diversity, asymmetry, or measurements,[36] despite available photographs and publications that include normative measurements. The lack of available knowledge is also reflected in parent and guardian understanding. McQuillan et al's study showed that among patients referred to a hospital for concerns regarding labial appearance, 24% of mothers were the first to express concern regarding the appearance of their daughter's genitalia, despite all patients having healthy genitalia.[37]

Evidence-based acknowledgment and communication on vulvar diversity in terms of appearance and ethnic background may support and empower adolescents, who tend to compare their own bodies with unrealistic media images. Nonmedicalized initiatives such as the "Labia Library,"[38] the "Vulva Gallery,"[39] or the "Vulvaversity" project[40] aim to show the diversity of female genital organs. These educational resources may also be useful in clinical practice to inform individuals seeking cosmetic genital surgery. It has been shown that a holistic sexual education, including conversations about genital anatomy and body image, can also improve protection against sexual abuse and other unhealthy sexual activity, such as unintended pregnancy and sexually transmitted infections.[41,42]

Limitations

Several limitations were identified while conducting this systematic review. First, there was a lack of description regarding changes in the outer labia, vestibule, and mons pubis. Second, among studies analyzing specific vulvar structures, measurement methods varied due to differences in the measuring positions and reference points used. For each vulvar structure, the articles also focused on slightly different outcomes; some focused only on hymenal configuration, whereas others included descriptions of hymenal features. Some authors used more qualitative approaches in describing hymenal configurations or labial symmetry and others more quantitative approaches with measurements of length and width, which limited the comparability of studies and limited our synthesis to a narrative approach. Third, there was largely insufficient detail regarding potential variations in vulvar morphologies across different ethnicities.

Finally, the quality of the included studies was mixed, with limited identification of confounding factors and a lack of detail regarding study subjects and setting often introducing a high risk of bias. The number of participants was also often quite limited, which reduced the reliable interpretation and comparison of results. Regarding the inclusion of studies, this review is subject to a selection bias due to the exclusion of gray literature, which may have resulted in the omission of relevant unpublished data.

Conclusion

In conclusion, this systematic review highlights some of the morphologic changes of the vulva during puberty, including an increase in the clitoral diameter, the length and width of the inner labia, and thickening of the hymenal membrane. There is a high variability in vulvar morphology and appearance between individuals. Currently, there is insufficient data to categorize vulvar pubertal development into stages, as has been done for other secondary sexual characteristics. This reinforces the need for a new, high-quality longitudinal study analyzing the changes of each structure and the correlation and chronology between them. This would provide patients with reliable information regarding how vulvas develop and would help HCPs to differentiate between physiological and pathologic variants.

Moreover, acknowledgement of the diversity of vulvas may be important for all individuals in terms of empowerment and improvement of self-esteem.

Conflicts of Interest

The authors report no conflicts of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpag.2025.01.002.

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