**Understanding the Functional Significance of the Labia Minora: A Scoping Review on Sexual Physiology**

## Introduction

The labia minora, a vital yet understudied part of female genital anatomy, are two inner folds of skin that extend outward from the vaginal and urethral openings, encompassing the vestibule. Part of the ectodermal-derived vulva, the labia minora stretch from the clitoris obliquely downward, laterally, and backward on either side of the vulvar vestibule, terminating between the base of the vestibule and the labia majora[1]. The posterior ends of the labia minora typically converge at the midline, connected by the frenulum.

The labia minora have been postulated to play a role in the female sexual response (FSR), a complex interplay of physiological, psychological, and anatomical factors[2–4]. Specifically, the labia minora has been reported to have rich vascularization and a high concentration of nerve endings, which may contribute to vascular engorgement and heightened sensation and arousal, respectively, during sexual activity[5,6]. Yet empirical evidence to link these anatomical characteristics with FSR remains sparse. While research on the role of the vulvar vestibule[7,8] and clitoris[9,10] in FSR has made significant strides in recent years, the labia minora has yet to be comprehensively reviewed.

Furthermore, individual variations in labial morphology have been widely established, highlighting the need for a nuanced approach to studying the role of the labia minora in sexual function[11]. While some women may experience heightened sexual pleasure due to specific anatomical characteristics of their labia minora, others may encounter challenges related to discomfort or dissatisfaction[2]. The interplay between anatomical variability and sexual function is complex and warrants investigation to provide evidence-based insights into clinical practice and sexual health education.

In light of these considerations, this paper aims to identifiy and critically assess the existing literature on the sexual function of the labia minora, identify gaps in current knowledge, and propose directions for future research. By elucidating the physiological mechanisms and anatomical correlates of the labia minora in sexual function, this study seeks to contribute to a comprehensive understanding of female sexual health.

## Methods

The objectives, inclusion criteria, and methods for this systematic review were specified in advance and documented in a protocol[12]. The Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR)[13] was used to guide the reporting in this study and standard methods were followed; checklists can be found in Supplementary Table 1. The protocol has been registered in PROSPERO (CRD42024519600) a priori.

### Search Strategy

A comprehensive search of the literature was conducted in biomedical, public health, and social science databases, including PubMed, Web of Science, Scopus, Global Index Medicus, Science Direct, Google Scholar, Cochrane Library, and HINARI to identify relevant articles published from inception of database through to March 2024. The final searches were performed in all the databases on March 31, 2024. Databases were searched using a combination of controlled vocabulary and free text terms for labia minora and characteristics related to sexual function. Details of the full search strategies are listed in Supplementary Table 2.

### Evidence Screening

The eligibility criteria for this scoping review were based on the PCC (Population, Concept, Context) framework, as recommended by the Joanna Briggs Institute (https://jbi.global/critical-appraisal-tools). Population: Studies involving cis females without congenital abnormalities of the vulva or ambiguous genitalia. Concept: Studies examining the gross and microscopic anatomy, innervation, vasculature, or sexual function of the labia minora. Context: Studies conducted across various settings, including clinical,

anatomical, and histological studies. No geographical restrictions were applied. Additional eligibility criteria included peer-reviewed articles, studies in English, and original research (quantitative, qualitative, or mixed methods). Studies were excluded if they were preprints, conference abstracts, narrative or literature reviews, case reports, studies not available in English, and those with an unclear methodology or focus on populations outside the defined eligibility criteria.
These criteria were developed to ensure the inclusion of relevant and high-quality studies while maintaining consistency and replicability.

The Rayyan Software (https://new.rayyan.ai/) was used to aid in the screening process. Duplicate publications were immediately excluded. The screening process was conducted in two phases: 1) title and abstract screening, where two independent reviewers screened all titles and abstracts retrieved from the database searches to assess their relevance based on the eligibility criteria, and 2) full-text screening where relevant abstracts were reviewed in full-text format to confirm eligibility. Full-text articles that did not meet the inclusion criteria were excluded, with reasons for exclusion documented. Conflicts at either stage were resolved through discussion and, if necessary, adjudication by a third reviewer.

**Data Extraction**

Three independent reviewers extracted variables from the full texts of included studies. A full list of variables extracted can be found in Supplementary Table 3. Data were entered into a 'data charting form' using Google Forms, which captured general information about the study characteristics, population demographics, intervention, outcomes, and study design.

**Assessment of risk of bias**

Manuscripts were assessed for the quality of evidence using the Oxford Centre for Evidence-Based Medicine (OCEBM) Levels of Evidence (https://www.cebm.ox.ac.uk/resources/levels-of-evidence/ocebm-levels-of-evidence). This scale grades manuscripts from 1 (highest) to 5 (lowest) based on their study design. Studies were also assessed using the JBI Critical Appraisal Checklist (https://jbi.global/critical-appraisal-tools). Given the scope of this review, which included studies with diverse methodologies, the combined use of these tools offered a more comprehensive evaluation of evidence quality. The OCEBM Levels of Evidence provided a hierarchical framework for categorizing studies based on design, while the JBI checklist ensured a detailed critique of each study's methodological rigor. Together, these tools allowed for a robust and multidimensional assessment of the included literature, supporting the validity and reliability of the review findings.

**Data Analysis**

The data analysis focused on systematically organizing and descriptively summarizing the characteristics and findings of the identified studies to provide a comprehensive overview of the current state of knowledge on the labia minora and its role in sexual function. We conducted a quantitative, qualitative, and formal narrative synthesis of the extracted data. Study methodologies, populations, and key outcomes were tabulated to highlight trends and contextualize findings within the broader research landscape of female sexual health. A thematic analysis was conducted to identify key patterns across studies, such as anatomical, vascular, and functional aspects, while also mapping evidence to highlight areas of concentration and research gaps, including limited exploration of hormonal influences and androgen receptors. Furthermore, it emphasized the descriptive mapping of evidence and thematic insights. While a risk-of-bias assessment was performed to enhance rigor, the primary aim was to identify gaps in the literature and provide direction for future research and clinical practice. By mapping the evidence and summarizing trends, this analysis contextualizes the findings and underscores areas where further exploration is needed to advance the understanding of the labia minora within female sexual health.

## Results

**Study Selection**

The literature search identified 480 entries, which represents 345 unique articles after duplicates were removed. After abstract screening, 60 articles were included for the full-text review, where 27 articles matched the inclusion criteria and were included in this review. The PRISMA Flow diagram is illustrated in Figure 1. All the selected articles were published between 1975 and 2024, described and evaluated the labia minora. Study characteristics are presented in Supplementary Table 3.

**Figure 1.** PRISMA flowchart. Additional information on screening methodology can be found in the supplementary material.

The included studies span a wide range of years, encompassing diverse methodologies and designs to investigate the anatomy, physiology, and clinical implications of the labia minora. Majority of studies (n=11) utilized a cross-sectional design (Figure 2A). Data collection methods varied, with the majority of studies utilizing direct clinical measurements (n=22), followed by surveys or questionnaires (n=12), imaging techniques such as MRI and ultrasound (n=8), immunohistochemistry (n=4), and observational approaches (n=3) (Figure 2B). Among the surveys used, the Female Sexual Function Index (FSFI) was the most frequently employed (n=6 studies), followed by the McCoy Female Sexuality Questionnaire (MFSQ) (n=5) and the Beck Depression Inventory (BDI) (n=5). These varied approaches reflect the multidimensional nature of research on the labia minora, addressing both anatomical and psychosocial factors.

The studies were conducted across multiple countries, with the largest number originating in the United States (n=9), followed by Italy (n=6), Spain (n=5), and Turkey and Germany (n=3 each). Other contributing countries included Canada, China, France, Egypt, the Netherlands, Sweden, and Czechoslovakia, highlighting the international scope of research in this field (Figure 3B). Sample sizes varied widely, with some studies focusing on small cohorts of cadaveric specimens or post-surgical tissues, while others included larger cohorts of live participants. Of the included studies, 17 focused on participants within reproductive age (15–50 years), while 9 included subjects outside this age range (Figure 3C). Additionally, 11 studies specifically included menopausal participants, providing valuable insights into the hormonal and life-stage-related changes in labial morphology and function (Figure 3D).

Overall, the risk of bias assessment using the Oxford tool revealed that study quality was mixed, with variability in methodological rigor across studies. While some studies demonstrated strong methodological approaches with robust data collection techniques, others had limitations related to sample size, measurement consistency, and reporting transparency. This heterogeneity in study quality underscores the need for standardized methodologies in future research on the labia minora.

**Figure 2.** Study Design of included studies (A) and type of data collection (B).

**Figure 3.** Studies by region. (A) Continent of origin and (B) country of origin. Study population in reproductive years (C) and menopausal status (D).

**Risk of bias of included studies**

Although risk of bias assessment is not mandatory for a scoping review, we included it to enhance the rigor of our analysis by evaluating the credibility of study outcomes. Of the included studies, 37% (10) were Level 2, 4% (1) were Level 3, 56% (15) were Level 4, and 4% (1) were Level 5. Evidence quality, assessed using the JBI Critical Appraisal Tool, was generally good, with over 90% of studies scoring “yes” in three or more domains. 56% (15) of studies received a “high” overall appraisal, 41% (11) were rated as “moderate,” and 4% (1) as “low.” Detailed quality assessments are provided in Supplementary Table 4.

**Synthesis of results**

The main outcomes fell into four themes: anatomy, vascularization, innervation, and sexual function (Figure 4)

**Figure 4. Summary and take-home messages of thematic areas identified.**

## Anatomy

Seven articles investigated the anatomy of the labia minora. Two studies used cadaveric specimens[14,15] and five studies examined live subjects[16–20] with the goal of furthering understanding the anatomy of the labia minora.

### *Gross Anatomy*

Ginger et al. described the gross anatomy of the labia minora using cadaveric specimens, characterizing the labia minora as folds of tissue situated between the introitus and the labia majora. These folds extend laterally from the interlabial sulcus to the introitus medially. The study defines the superior aspect of the labia minora as inserting on the ventral aspect of the clitoral glans or frenulum, with the inferior tip inserting at the inferior aspect of the vaginal introitus. The labia minora is clearly demarcated from the labia majora by the absence of adipose tissue in the labia minora, in contrast to the abundant adipose tissue found in the labia majora[6,14]. It has been hypothesized that the labia minora function to shield the vestibule from mechanical irritation, dryness, and infections[21,22]. This protective role is attributed to the fact that the vestibule is derived from endodermal tissue, which is more susceptible to these issues, compared to the ectodermally derived labia minora, which possess relatively greater structural resilience. Several studies have explored the asymmetry of the labia minora. For instance, Cao et al. 2021[15] used cadaveric specimens and discarded labial tissue to report that 67% of their study population exhibited asymmetry. Conversely, Kaya et al. 2018[18] found that 31.5% of the 89 participants had asymmetry, while 68.5% had symmetric labia minora. Cao et al. 2021[15] based their findings on cadaveric specimens and discarded tissue samples whereas Kaya et al. 2018[18] collected measurements from live participants. The use of cadavers and surgically removed tissues can impact measurement accuracy, as tissue shrinkage and size changes can occur post-mortem and after the cessation of perfusion. Additionally, these studies did not clarify whether peri or postmenopausal patients were included, which could be significant, as vulvovaginal atrophy due to estrogen loss in this population may influence labial size[23]. The inconsistency in asymmetry findings across studies underscores the need for further research to determine the prevalence of labial asymmetry accurately. The Kaya et al. 2018[18] study had limitations, including the exclusion of three patients with asymmetric labial diameters who did not meet inclusion criteria. Additionally, only six patients in this study had a labium minus width of 40 mm or more, potentially due to the study population's composition, which primarily consisted of patients seeking interventions for non-cosmetic gynecological reasons. This may have led to an underestimation of the prevalence of labial asymmetry in the general population.

### *Labia Minora Width*

The width of the labia minora has been assessed using various methods, including digital calipers[16], 2D US imaging [19,20], and 2D MRI imaging[17]. Studies have reported significant variability in labial width, influenced by factors such as age, hormonal status, and individual anatomical differences[23,24]. For instance, Cao et al. 2021[15] reported mean labial widths of 20.94 ± 6.50mm (left) and 20.11 ± 5.92mm (right) in cadaveric specimens, but the lack of age stratification limited the interpretation of how these dimensions change across life stages (Table 1). This omission is significant given the known changes in labial anatomy during puberty and the regression that occurs during and after menopause[23,24]. In contrast, Suh et al. 2004[17] observed age-related differences, with premenopausal women having wider labia (11 ± 2 mm) compared to postmenopausal women (9 ± 2 mm), consistent with vulvovaginal atrophy due to decreased estrogen levels. These findings align with the well-documented trend of vulvovaginal atrophy and a decrease in tissue size following menopause[23].

Kaya et al. 2018[18] conducted a study measuring labia minora width bilaterally, dividing the labia into three sections based on the Banwell classification[25] and utilized the Mokatef classification[26] to categorize labial protrusion (Table 1). Notably, there is a large range and variation in the natural size of the labia minora that has been reported in the literature, and it has also been observed that the size of the labia can change over time[11,27]. The fact that the patient population in the study analyzed were majority multiparous and study design lacked stratification by participant weight could introduce confounding variables. Such studies emphasize the need for broader investigations to better characterize labial anatomy and its natural variations. A more detailed exploration of labial asymmetry, which is commonly observed, is also warranted. Many women present with asymmetrical labia, yet societal and cultural norms often label these differences as "abnormal," contributing to misconceptions about female genital anatomy. Future research should seek to clarify the range of labia minora width in order to demedicalize non-pathological labia and educate the public on diverse genital appearance.

The concept of labial asymmetry, while physiologically normal and widely prevalent, has not been adequately addressed in clinical or public discussions; many women are unaware of the wide variability in normal anatomical structures. This lack of awareness can contribute to psychological distress, as women may feel pressured to conform to unrealistic ideals of genital appearance. Such distress can negatively impact sexual self-esteem and overall sexual health. Vulvar psychology, particularly as it relates to perceptions of "normalcy," plays a critical role in shaping sexual self-esteem and may in part contribute to an increase in demand for labiaplasty. While labiaplasty can alleviate discomfort caused by hypertrophic labia during physical activities or intercourse, it is often sought to achieve an idealized appearance. A detailed discussion of the motivations for labiaplasty, its outcomes, and its potential impact on sexual self-esteem is essential. Clinicians must adopt a patient-centered approach when addressing concerns about labial appearance, emphasizing the natural diversity of genital anatomy and dispelling harmful stereotypes. Public health education campaigns can play a critical role in normalizing labial variability and promoting body positivity.

Interestingly, several intrinsic factors have been reported to affect the width of the labia minora. Battaglia et al. 2012[19] observed that labia minora thickness varied across the menstrual cycle, with measurements taken during the follicular phase being significantly smaller than during the periovulatory phase. This finding suggests a positive correlation between estradiol levels, which peak around the periovulatory phase, and labia minora thickness. Estradiol's effect on labial thickness may be explained by its enhancement of nitric oxide (NO) production through increasing expression and activity of endothelial nitric oxide synthase (NOS)[28]. NO subsequently raises cGMP levels and allows calcium influx into the vascular labia minora, causing vasodilation and resulting in labial engorgement[17]. However, studies have observed a significant decrease in labia minora thickness after three months of treatment with a combination oral contraceptive pill (OCP) containing 30mg ethinylestradiol and 3mg drospirenone[29]. While estriol is associated with increased labia minora thickness, the exogenous administration of combination estrogen and progestin, like drospirenone in OCPs, has the opposite effect. OCP-induced hypoestrogenism is well-documented[30–32], and linked to an increased resistance of the posterior labial artery, contributing to reduced labial thickness[20]. Furthermore, OCPs are known to lower androgen levels, which may further reduce labial thickness, though the role of androgens in labia minora morphology remains unclear[33,34]. Further research is needed to elucidate androgen influence on the anatomy and physiology of the labia minora.

One study investigated labia minora width in regards to the FSR, where labia minora width was measured before and after arousal induced by an erotic film[17]. They found that labia minora width increased significantly in both pre- and postmenopausal women, as well as MRI signal enhancement. However, it is important to consider that the study used only psychogenic stimuli (an erotic film) to induce arousal,

which may have affected the degree or capacity of arousal achieved by participants, potentially influencing the results.

### *Microanatomy Histological Characterization*

Five studies investigated the microanatomy of the labia minora tissue through histological characterization[5,6,14,35,36] (Table 2). From cadaveric and discarded surgical tissue samples, the labia minora is consistently described as being lined by stratified squamous epithelium with papillary protrusions, and melanocytes distributed throughout the basal layer of the epithelium[5,15]. The epidermis of the labia minora comprises four layers: the basal layer, spinous layer, granular layer, stratum corneum, and a superficial cornified layer. Beneath this, the dermis was reported to have a papillary structure with fine collagen, reticular, and elastic fibers, and a deeper reticular layer with collagen and elastic fibers[5]. Sebaceous glands and eccrine sweat glands were also identified, with openings to the skin's surface through sebaceous glands. In postmenopausal women, the labia minora epithelium was found to be more thinly keratinized[6]. The labia minora were also noted to have an abundance of elastin fibers and a lack of smooth muscle, thought to be related to the labia minora's function in engorgement during sexual arousal[6,14].

Martin-Alguacil et al. 2008[35] conducted immunohistochemical (IHC) staining to investigate estrogen receptor (ER) expression in the labia minora. They found ER-α staining on cell membranes of fibroblasts as well as basal and suprabasal epidermal cells in the superficial labia minora, and ER-α nuclear staining in the stroma localized superiorly near the clitoris[35]. ER-β staining was more concentrated in the basal epidermal and apocrine glandular epithelial cell membranes (Table 2). Clinical implications of these findings are demonstrated through a case report of a 29-month-old girl from Italy who presented with labial adhesions which were resolved with topical estriol[37]. Although the precise pathophysiology of labial adhesions remains unclear, they are thought to develop due to the low endogenous estrogen in young girls, exacerbated by the thin and immature nature of the labia minora[38]. The patient's favorable response to estriol 0.05% cream underscores the presence of estrogen receptors in the labia minora and suggests a potential treatment approach for labial adhesions in young, prepubertal girls[35]. It is important to note that research on the presence of androgen receptors in the labia minora is scarce. Hodgins et al. 1998[39] reports androgen receptors in the epidermis of labia minora, but further characterization and understanding of clincial implication is largely lacking.

## Vascularisation

### *Blood Vessel Morphology*

Vascularization of the labia minora was investigated by five papers[15,18,40–42]. Collectively, these studies report four main arteries supplying the labia minora: a central dominant vessel along with two posterior arteries and one small anterior artery, all of which anastomose along the edge of the labia minora[15,18,40–42]. The origin of the blood supply involves the external and internal pudendal arteries in creating anastomoses[15,18,42]. The external pudendal artery is described as the communication between the posterior labial arteries, where two additional collateral arteries communicate between this posterior system and the internal pudendal artery on the anterolateral aspect of the labia minora[42]. Moreover, the external pudendal artery plays a role in the perfusion of the clitoris and communicates with the posterior system via the frenulum arteries, connecting blood supplies at the mucosal surface of the anterior part of the labia minora[42]. Additionally, the superficial pudendal artery was observed to supply both the skin of the labia minora and the foreskin of the clitoris[15,18]. Regarding the anatomic journey of the blood vessels through the labia minora, the dominant central artery is reported to project perpendicular to the long axis of the labia minora[42]. When the edge of the labia minora is reached, the artery continues coursing under the edge in a posterior to anterior direction, fading as the anterior part of the labia minora is reached[18,42]. The edge artery is characterized as the anastomosis between anterior and posterior arteries[18]. Lack of coloration of the most anterior part of the labia minora with latex injection suggests that the more anterior labia minora represents the least perfused part[42]. The two posterior arteries and the smallest anterior artery were

reported to have a perpendicular trajectory to the long axis of the labia minora[42]. Finally, the base artery is at the introitus indicating anastomosis with the internal pudendal artery[18] (Figure 2).

To investigate labia minora arterial morphology one study used cold light illumination to assess whether the central dominant labial artery coursed medially, superior, or posterior, as well as any differences between left and right labia minora[18]. The authors reported that in 93.3% (n=83) of all cases, regardless of whether the artery was medial, superior, or posterior, the artery was observed on the right labia minora[18]. The significance of having right-sided-dominant arteries is unclear, and further research should investigate whether there are any functional anatomical or clinical implications associated with right versus left-sided arterial prominence. One limitation of this study is that in using cold light illumination it is not possible to precisely distinguish between arteries and veins, introducing potentially biased results. A study performing contrast dye injection and rotational angiography on fresh cadavers investigated labia minora arteries emergence[42]. The authors reported that the central artery typically emerges around the midpoint of the labia minora, at about the 55th percentile of its length. The two posterior arteries emerge closer to the posterior end, at the 17th and 32nd percentiles [42]. Lastly, the small anterior artery is located towards the anterior end, at the 76th percentile of the labia minora's length[42].

**Figure 5.** Vascular Morphology of the Labia Minora. 1: Branch of external pudendal, 2: Superficial pudendal, 3: Edge artery, 4: Anterior artery, 5: Central dominant artery, 6: Posterior artery, 7: Base artery, 8: Branch of internal pudendal.

***Microanatomy and Histology of Vasculature***

Microanatomy investigation of the labia minora has provided insight into its vasculature characteristics. Authors consistently report that the labia minora contains vascular tissue immediately deep to the epithelium, and is composed of vessels embedded in fibrous tissue rather than smooth muscle[6,14]. The tissue contains variably-shaped vascular spaces, which are postulated to accommodate volumes of blood during arousal[14], supported by MRI studies[6]. These findings were consistent regardless of menopausal status[6]. Moreover, PDE4 markers were reported in vascular labia minora tissue, with significant PDE4 expression observed in the arterioles of the subepithelial layer and PDE5 expression in the vascular smooth muscle[43](Table 2). PDE4 has been shown to contribute to endothelial and epithelial barrier stability[44]. In contrast, PDE5 in vascular smooth muscle degrades cGMP, allowing vasorelaxation; in penile arteries during male erection inhibition of PDE5 allows cGMP to accumulate and activate a cascade of downstream phosphorylation and dilation of blood vessels[45]. However, whether the roles of PDE4 and PDE5 in the vasculature of the labia minora function similarly to their roles in the penis is unclear. Further research is needed to clarify their specific functions and significance in labia minora physiology.

The vasculature of the venous system has received far less attention than the arterial network. Venous distribution has been described as having similar anastomotic branching in the same direction as arteries[15]. Additionally, deep veins from Kobelt's plexus are reported to penetrate the tunica albuginea of the clitoral cavernosa, traversing the angle of the clitoris between the glans and the corporal bodies, meeting the lamina propria of the anterior vestibule[36]. Kobelt's plexus and the surrounding stroma form the pars intermedia, a key structure in the sexually responsive nonerectile tissues of the labia minora, coordinating differential drainage following sexual arousal and engorgement[36,46]. Future research should investigate the FSR as it relates to venous drainage during arousal and orgasm, compared to basal conditions.

***Clinical Implications***

Three articles in our review emphasize the critical importance of accurately identifying vascular morphology when planning surgical procedures involving the labia. Kaya et al. 2018[18] stratified patients based on the upper, middle, or lower position of the central artery in the labia minora, finding a significantly higher percentage of the central vessel in labia with an upper morphology compared to those with a lower morphology[18]. This highlights the need to consider the extent of central vasculature disruption during surgery. For example, labiaplasties, which are often performed using a wedge resection technique, require a choice between anterior, posterior, or central wedge approaches[47]. In labia with a lower morphology, the central vessel is located lower, with the posterior vessel branching from it[18]. A posterior wedge resection in these cases can severely disrupt blood flow by cutting the main artery. Conversely, in labia with a middle morphology, the posterior vessel is positioned higher, increasing the risk of cutting the central vessel during a central wedge resection. These findings underscore the importance of tailoring surgical techniques to each patient's specific vascular map to optimize outcomes and minimize bleeding risks during labiaplasties. In addition to wedge resection, another labiaplasty technique is de-epithelialization. It was first proposed by Choi et al. 2000[48] that a wedge excision sacrifices major vessels which may result in dehiscence, and that a de-epithelization technique solves this problem[48]. However, Choi assumed that with de-epithelization, the labial vessels are preserved. The more recent findings of Georgiou et al. 2015[42] reported that the arteries of the labia minora run just under the mucosa of the skin and not in the central core of the labia minora, such that even de-epithelialization may interrupt these vessels. Having this model in mind, labiaplasty techniques should be discussed in terms of arterial flow preservation. It is crucial to understand the implications of surgical interventions and the potentially life-altering complications that can arise if individualized vascular morphology is not considered.

## Innervation

Critical to understanding the functional and clinical importance of the labia minora is comprehensive knowledge of its innervation. Of the 26 papers we included, 14 focused on the innervation of the labia minora. Among these, five analyzed cadaveric specimens[14,15,42,49,50], seven examined surgical specimens[5,15,40,50–53], and five examined live human subjects[40,41,54–56]. Various methods were used to evaluate neuroanatomy: six papers employed immunohistochemistry[5,15,35,49,52,53], three used gross anatomical observation and measurements[14,40,51], one utilized radiologic imaging[42], one conducted nerve conduction studies[56], two performed sensory testing[54,55], and three performed qualitative assessments of sensation[40,41,57].

### *Gross anatomy*

A cadaveric study using computed tomography with contrast suggested that the neuroanatomy of the labia minora originates from the pudendal nerve[42]. Though the sample size was small (n=9), the anatomy found was consistent in all cases observed. Two studies found that once neural branching occurs in the labia minora, the network is largely concentrated to a central neural core extending the length of the labia minora and traveling alongside vascular structures[14,15]. Indeed, nerve count has been reported higher in the medial region than the lateral region[15], with higher overall nerve and nerve bundle density in the superior middle region of the labia minora[40,49].

### *Nerve Endings*

In the labia minora, sensory nerve endings are reported to include free nerve endings, arborizations, spray-like endings, clew-like nerve endings, and Pacinian-like corpuscles[50]. A collective hypothesis from three independent studies has emerged that labia minora central core nerves are predominantly clew-like formed by one or more thick branching myelinated afferent axons with large nucleated Schwann cells and small nerve fibers toward the edges[14,15,50]. The average length of clew-like endings was reported to be 256μm with an average width of 199μm, where thickness and variation in nerve endings were independent of age[50]. Free nerve endings, identified via Cajal-type silver staining, were found to pass through the dermis and terminate in the stratum granulosum, basale, and spinosum of the epidermis[5].

Nerve density was reported to be most concentrated at the subepithelial plexus as well as at basal and spinous layers of the exterior epithelium[5]. Interestingly, in a study examining the sensory nerve endings in hypertrophic labia minora, the rate of occurrence of genital corpuscles was significantly higher (28.43%) in hypertrophic labia, compared to control (10.2%), which the authors suggest to be indicative that hypertrophy may be related to an underlying growth factor that induces nerve growth[51].

***Histological Molecular Characterization***

Immunostainng of the labia minora has consistently reported peripheral Pacinian-like corpuscle of the labia minora[5,15,50,53]. The corpuscle itself, initially elucidated by Mason's trichrome, demonstrated an axon surrounded by an inner core with 5HTT and neuropeptide Y (NPY), outer core with positive PGP 9.5, 5HTT, 5HT1A, neuron specific enolase (NSE), and ERα, and an external capsule with PGP 9.5, neuronal nitric oxide (nNOS), and ERα positive staining[53] (Table 3). PGP 9.5, NPY, and NSE are all nerve-specific markers, while 5HTs are serotonin receptors, and nNOS is a vasodilator and mediator of synaptic plasticity. Evidently, neuroprotection, neurodegeneration, and neurovascular interplay of the labia minora appear to be serotonin, estrogen, and nitric oxide mediated. Interestingly, nNOS and S-100, a neural marker, stain more intensely and widespread at the introital border versus the exterior border of the labia minora[5,35]. Subsidiary innervation in the stroma was positive to VIP and NPY[53] (Table 3). NPY is a pleiotropic peptide involved in vasoconstriction and inflammation[58,59]. Various dermatologic pathologies are partially explained by genetic variations in NPY and modulated by inflammatory stress[60]. VIP also acts as an immunoregulator[61].Variations in the genetic disposition of these peptides may have a role in labia minora function such as immunomodulated dermatose pathologies, highlighting the need for further investigation to improve clinical diagnosis and outcomes.

**Consolidation of Sexual Function Evidence of the Labia Minora**

Integral to the fundamental understanding of the labia minora is a thorough understanding of their role in sexual function. Despite this importance, this review identified limited literature focused on defining their sexual function; of the 28 papers included in this study, ten examined sexual function. Among these, nine used questionnaires: four studies used the Female Sexual Function Index (FSFI)[16,40,41,54], three studies used the McCoy Female Sexuality Questionnaire (MFSQ)[20,29,62], one study used both FSFI and MFSQ[63], and one study used the Index of Female Sexual Function[55]. While most studies used a questionnaire to evaluate sexual function, few focused on the sexual function of the labia minora, and instead examined the relationship between lifestyle or comorbidities (pregnancy, diabetes, alcohol, smoking, oral contraception) on sexual function. Six papers posited connections to the possible roles of the labia minora in sexual function based on original physiological evidence[16,20,53,62–64].

The finding of abundant clew-like and pancianin-like corpuscles to the labia minora suggests their role as sensory organs crucial to female sexual arousal[53]. Pacinian corpuscles are well-known for their role in sensory perception and rapid response to pressure, and similar corpuscles have been identified in the clitoris, the primary organ involved in sexual arousal[65,66]. The finding that these labia minora corpuscles contain ERs, indicates that hormonal fluctuations—such as those occurring during the menstrual cycle, pregnancy, or menopause—could influence their function, potentially altering the labia minora's ability to become aroused, engorge with blood, and participate in the FSR[53].

Two studies analyzed the pulsatility index (PI) of the labial artery in association with sexual function[20,63]. The PI is a non-invasive method of assessing vascular resistance with Doppler ultrasonography[67]. One study found that as the PI of the posterior labial artery decreased, the labia minora thickness increased, indicating that lower resistance in the labial artery allows for easier engorgement, leading to the observed increase in labial thickness[63]. Further, as the labia minora became thicker, so too did the patient-reported frequency of intercourse, purported to be due to increased arousal of the genital tissues[63]. A different study examining smoking and sexual function via Doppler histogram analysis of labia minora vascularization, reported that the labia minora PI progressively increased from non-smokers to current

heavy smokers ($p \leq 0.01$)[20]. As a high PI is associated with increased vessel resistance and thereby decreased engorgement function, it was concluded that current heavy smokers may experience a decreased FSR due to impeded vascularity, likely attributed to atherosclerosis of labial arteries from carcinogens[20]. Taken together, these findings indicate a link between vascular responsiveness in the labia minora and sexual function, suggesting that PI may be a useful tool in assessing the FSR of the labia minora.

A cohort study involving two groups watching a neutral and erotic film in different orders examined labia temperature changes to explore the sexual function of the labia minora.[54]. The study found that participants who watched the neutral film first experienced a significantly higher increase in labia temperature during the erotic film compared to those who watched the erotic film first[54]. This suggests that initial exposure to neutral stimuli may maximize sexual response, possibly due to increased comfort in the testing environment or a lack of baseline sensory testing. The study also indicated that the labia minora plays a role in sexual arousal, as the observed temperature increase correlates with increased blood flow[54]. However, the study's focus on pain response rather than pleasure may have skewed the results, and further research is needed to clarify the link between labia minora temperature, blood flow, and sexual function.

One study used the modified Clark oxygen electrode to examine the difference in labia minora arterial blood flow between basal, self-stimulation, and orgasm, utilizing pO2 levels[64]. This study reported that from baseline levels ($18.3 \pm 3.7$mmHg), upon initiation of sexual self-stimulation, there was a significant increase in oxygen tension in the labia minora which peaked ($47.3 \pm 4.$mmHg) immediately after orgasm began[64]. Once the orgasm ended, there was a decrease in oxygen tension in the labia minora, but post-orgasm oxygen tension in the labia minora remained higher than at baseline levels for 20-30 minutes[64]. Given the substantial changes in pO2 in the labia minora before and after orgasm, these findings suggest a role of pO2 in the labia minora and sexual function. Namely, it is possible to infer that the labia minora could support an increase in blood flow and engorgement function in the FSR. Further investigation is needed to understand how the changes in vasculature of the labia minora contribute to orgasm.

Overall, most of the data examining the sexual function of the labia minora focused on blood flow, and other ways that the labia minora may impact sexual function have been largely ignored. Additional studies are needed to explore the possibility of changes in labia minora function, sensitivty, and innervation attributed to pacinian-like corpuscles with serotonin and ER receptors. Furthermore, research related to altered hormonal state should be investigated, and the presence of androgen receptors in should be investigated. Additionally, the order of blood flow between the labia and clitoris, and the relationship between the two needs to be better understood. It is unclear whether blood flows sequentially or in parallel, or if blood flow from the labia facilitates blood flow to the clitoris and vice versa.

**Labia Minora Over a Lifetime**

The labia minora undergo significant changes throughout a woman's life, starting as almost absent in the prepubertal stage, growing in size during puberty, and eventually resorbing during menopause[24]. This pattern of growth and regression has not been extensively studied, leaving a gap in our understanding of its physiological and developmental significance. Notably, the development of the median raphe in males, which forms early in fetal life, suggests a possible role of androgens in the development of the labia minora, given that the labia minora is the female homologue to the median raphe[69,70]. This hypothesis is further supported by observations in patients with congenital adrenal hyperplasia (CAH), who may offer valuable insights into the androgenic influences on labia minora development and function[71–73]. These observations underscore the need for further research to explore the hormonal and developmental factors influencing the labia minora across different life stages.

**Limitations**

The included studies in this review present several limitations that highlight the need for further research. Methodological variability, such as differences in study designs—ranging from cadaveric to live subject studies and imaging versus histological techniques—complicates cross-comparisons of findings. Population biases are evident, with many studies relying on small or non-representative samples, such as cadaveric tissues or patients undergoing surgery for unrelated reasons. The reliance on cadaveric specimens, in particular, introduces potential limitations, as post-mortem changes such as tissue shrinkage, loss of vascular perfusion, and alterations in tissue elasticity may not accurately reflect the functional anatomy observed in living individuals. These factors can lead to under- or overestimation of measurements, particularly in studies examining vascularization and innervation. Furthermore, few studies stratified results by age or menopausal status, limiting understanding of how labial anatomy and function evolve across different life stages. Notably, there is evidence that the anatomy of the labia minora varies significantly depending on age and hormonal status, with changes such as decreased tissue size and vascularization observed in postmenopausal individuals. These variations underscore the need for a more in-depth discussion of how life stage, hormonal environment, and sample type influence labial morphology and function.

To address these gaps, future research should focus on comprehensive anatomical studies to establish population-based data on labial asymmetry, size variations, and normative ranges across ages and hormonal statuses. Investigating the relationship between androgen exposure and labial development, particularly in conditions like congenital adrenal hyperplasia (CAH), could offer valuable insights. Advanced imaging modalities, such as Doppler ultrasonography and angiography, could be employed to map arterial and venous systems under different physiological and hormonal conditions. These approaches would also help elucidate the interplay between labial and clitoral blood flow in sexual response. Understanding the functional roles of nerve endings and hormonal receptors, including estrogen, serotonin, and nitric oxide, in sensory function and arousal is equally crucial. Clinical correlations, such as the impact of labial morphology on sexual satisfaction and function, warrant exploration using validated tools like the Female Sexual Function Index (FSFI). Additionally, surgical guidelines must incorporate individualized vascular and neural maps to minimize complications during labiaplasty and other interventions, while non-surgical treatments for labial adhesions and atrophy should leverage hormonal and neurochemical insights.

Finally, limitations inherent to the scoping review methodology must be acknowledged. Exclusion of non-English studies may have omitted relevant findings from other regions, and the omission of grey literature, preprints, and conference abstracts may have narrowed the scope of included evidence. Moreover, as a scoping review, the focus was on mapping evidence rather than conducting in-depth synthesis or quantitative meta-analysis, limiting insights into specific outcomes. Nonetheless, by addressing these limitations and pursuing interdisciplinary, targeted research, future studies can deepen understanding of the labia minora's anatomy and function. This is particularly important for examining differences influenced by age, hormonal factors, and the type of specimen studied, improving clinical practices and advancing female sexual health.

## Conclusion

In summary, the labia minora likely plays a critical, but poorly understood, role in FSR. Studies have brought attention to rich vascularization and innervation patterns of the tissue, and their potential involvement in FSR through engorgement and sensory functions. Despite these insights, significant knowledge gaps persist, particularly concerning whether the anatomy of blood vessels is dependent on an individual's unique labial morphology (right vs left dominant, upper vs low prominence), the exact innervation pathways and locations of nerves, and the effect of androgens on the labia minora. This lack of knowledge impedes comprehension of these vital structures and hampers the ability to optimize procedures to minimize bleeding and prevent nerve damage. Additionally, the development of effective therapeutic interventions for vulvar-associated pathologies is compromised. Without a comprehensive

understanding, clinicians and researchers lack the necessary insights to develop treatments that preserve the function and overall well-being of affected individuals. Future research should prioritize detailed anatomical and physiological studies to fully explore the labia minora's role in FSR. Gaining deeper insights into the labia minora will enhance our knowledge of female genital anatomy and sexual health, helping to prevent complications and improve the diagnosis and treatment of related disorders.

| Author | Population Characteristics | Pre-/Post Menopausal | Method of Measurement | Mean Width (mm) | Significance |
|---|---|---|---|---|---|
| Cao et al 2021[15] | Cadavers (n=7): 47yo<br><br>Discarded Labia Minora Tissue (n =18): 28.89 yo | Postmenopausal | Not specified | Right labium minora width: 20.11 ± 5.92<br><br>Left labium minora width: 20.94 ± 6.50 | No hypothesis testing done |
| Kaya et al. 2018[18] | Patients who underwent any gynecological intervention excluding aesthetic genital surgery<br><br>(n= 89)<br>34.3 +/- 8.6 yo | pre- and postmenopausal | Not specified | Right labium minus width:<br>0-20mm, 51.7%<br>20-40mm, 47.2%<br>>40mm, 1%<br><br>Left labium minus width:<br>0-20mm, 16%<br>20-40mm, 41.6%<br>>40mm,4% | p = 0.017<br><br>p = 0.069 |
| Kaya et al. 2020[16] | Healthy, non-pregnant, no OCP or IUD use<br><br>(n=208)<br>35.2 +/- 9.1 | premenopausal | Digital stainless-steel Vernier caliper | Right labium minora width: 21.2 ± 8.6<br><br>Left labium minora width: 22.0 ± 9.6 | No hypothesis testing done |
| Suh et al 2004[17] | Healthy Women<br><br>Premenopausal (n=11): 30.3 years<br><br>Menopausal (n=8): 56.4 years | pre-and postmenopausal | 2D MRI | Labia minora, Premenopausal:<br>Neutral: 11 ± 2<br>During arousal: 13 ± 2<br><br>Labia minora, Menopausal:<br>Neutral: 9 ± 2<br>During arousal period: 10 ± 2 | p < 0.01<br><br>p < 0.01 |

**Table 1.** Summary of results from studies on labia minora width

| Author | Sample | Method | Marker | Findings |
|---|---|---|---|---|
| Schober et al 2010[52] | Waste tissue strips from the surgical separation of the labial fusion of 10 girls 2-9y/o | Waste tissue strips from the surgical separation of the labial fusion of 10 2-9y/o girls were taken. Tissue was stained with Masson's and Hematoxolin and Eosin, fixed, frozen and cut into 30μm sections. | H&E | Labia minora are lined by Stratified squamous epithelium. Epidermis has the typical 4 layers (basal, spinous, granular, and stratum corneum). The dermis is differentiated into papillary and reticular, with the latter containing vascular and lymphatic plexus surrounded by collagen and elastic fibers. The papillary was composed of fine collagen, elastic, and reticular fibers. Connective tissue papillae from this layer sometimes projected into the epithelium.Labia minora has dense sebaceous glands and eccrine sweat glands that open onto the skin. |
| Shih et al. 2013[36] | 9 cadaveric female vulvectomy specimens | Samples were embalmed and buffered in formalin for processing. All vulvectomy specimens were serially sectioned and submitted in separate cassette blocks. Serial sections were then stained with H&E to examine general histologic features. | H&E | The pars intermedia is composed of predominantly collagen-rich stroma supporting the veins of Kobelt's plexus, traveling longitudinally in the angle of the clitoris. Observed non-erectile specialized vascular tissue of the labia minora, which allows differential drainage following sexual arousal and engorgement to occur. |
| Martin-Alguacil et al. 2008[35] | Waste tissue strips from the surgical separation of the labial fusion of 10 girls 2-9y/o | Labial tissue was fixed in 4% paraformaldehyde, buggered, frozen and cut into 30μm thick sections. The specimens were incubated with rabbit anti-ER alpha, rabbit anti-ERbeta, and rabbit anti-nNOS. The sections were then processed in rabbit IgG Vectastain ABC Kit. | ERα | ERα present in the stroma of the labia minora near the clitoris and basal and suprabasal epidermal cells membrane in superficial labia minora |
| | | | ERβ | ERβ stained positively in the cell membrane basal and suprabasal epithelial cells as well as apocrine glandular epithelial cell membrane superficially. Lamina propria contained ERβ positive fibroblasts. |
| | | | nNOS | nNOS was diffusely distributed and corresponded with nerve bundles and fibers in the stroma of the labia minora. |
| Martin, Alguacil et al. 2011[53] | Waste tissue strips from the surgical separation of the labial fusion of 10 girls 2-9y/o | Labial tissue was fixed in 4% paraformaldehyde, buggered, frozen, and cut into 30μmthick sections. The specimens were incubated with rabbit anti-ERα, and rabbit anti-ERβ. The sections were then processed in rabbit IgG Vectastain ABC Kit | ERα | ERα present in the outer core, external capsule, and stroma of the Pacinian-like corpuscle of the labia minora |
| | | | ERβ | ERβ stained positively in the stroma of the Pacinian-like corpuscle of the labia minora |
| Uckert et al. 2007 [43] | Human labial tissue was obtained from 4 fresh female cadavers. | Vibratome sections prepared from formaldehyde fixed tissue specimens, and incubated with primary antibodies against PDE isoenzymes. Sections were then incubated with fluorochrome (fluorescein isothiocyanate, Texas Red)-labeled secondary antibodies. Visualization was commenced using a laser fluorescence microscope. | PDE3 | PDE3 was widespread in epithelial layer cells, epithelial sebaceous glands, and neuroendocrine labial epithelium cells |
| | | | PDE4 | PDE4 was diffusely present but prominent in arterioles throughout the subepithelial layer as well as vascular smooth muscle and vascular endothelium |
| | | | PDE5 | PDE5 was prominent in the vascular smooth muscle |
| | | | PDE11 | PDE11 was mainly registered in epithelial glandular-like structures |

**Table 2.** Histological Characterization of Labia Minora Tissue and Vasculature. Abbreviations: H&E, Haematoxylin & Eosin; ERα, estrogen receptor-alpha; ERβ, estrogen receptor-beta; nNOS, neuronal nitric oxide; PDE3, phosphodiesterase 3; PDE4, phosphodiesterase 4; PDE5, phosphodiesterase 5; PDE11, phosphodiesterase 11.

| Author | Method | Marker | Findings |
|---|---|---|---|
| Malinovsky et al. 1975[50] | Triangular resections of 5 surgical specimens and one cadaver was performed and divided into 3 parts, fixed immediately, and impregnated with silver nitrate. Evaluated 2,136 sensory nerve endings in total. | Silver nitrate | The labia minora consists of simple branched nerve endings, spray-like nerve endings, and most prominently, clew-like sensory nerve endings formed by one or more thick branching myelinated afferent axons with large nucleated Schwann cells and small nerve fibers toward the edges. They observed seven variations of the clew-like nerve endings, the most prominent being the Pacinian-like 'genital corpuscle' which contains a thick capsule. The average length of clew-like endings was reported to be 256μm with an average width of 199μm, independent of age. |
| Cao et al. 2021[15] | Surgical and cadaveric labia minora specimen were fixed in 10% formaldehyde, embedded in paraffin, sectioned, and processed. IHC performed using the S100 antibody to identify neurons. | S-100 | Abundant large myelinated sensory nerve endings in the central area of the labia minora and small, sparse, and dispersed nerve endings laterally. |
| Kelishadi et al. 2016[49] | Four fresh tissue cadaver labia minora were analyzed. Each labia minora was divided into 6 anatomic areas and analyzed for the presence of nerve bundles using H&E and IHC for S100. Nerve density was analyzed under light microscopy, counted, and then expressed as percentage nerve density as well as number of bundles per square millimeter. | S-100 | Though there is a higher trend toward overall nerve density in the superior outer and superior middle regions of the labia minora compared to inferior regions, these differences are not statistically significant, suggesting that sensory innervation may be heterogeneous throughout the labia minora. |
| Schober et al. 2010[52] | Waste tissue strips from the surgical separation of the labial fusion of 10 2-9y/o girls were taken. Tissue was stained, fixed, frozen and cut into 30μm sections. Specimens were incubated with rabbit anti-neuronal nNOS and rabbit anti S-100 dilution 1:400. Specimen was then processed with IgG Vectastain ABC kit. Some sections were stained with Bielschowsky silver stain. | Bielschowsky silver stain | Thick nerve fibers were found in reticular and papillary dermis while thin nerve fibers were throughout the dermis and epidermis. Nerve density was reported to be most concentrated at the subepithelial plexus as well as at basal and spinous layers of the exterior epithelium. Free endings and arborizations were described with spray-like endings and seven types of clew or ball-like nerve endings as well as Pacinian corpuscles were described. Dense nerve fibers surround vascular and lymphatic plexuses. |
| | | S-100 and nNOS | S-100 and nNOSwas found more intensely and widespread at the introital border versus the exterior border as well as at the subepithelial plexus |
| Martin, Alguacil et al. 2011[53] | Labial tissue samples were obtained following labial fusion. Immunocytochemistry against PGP 9.5, NSE, VIP, 5HTT, 5HT1A, NPY, nNOS, were performed. | PGP 9.5, NSE, VIP, 5HTT, 5HT1A, NPY, and nNOS | Pacinian-like corpuscle<br>Inner core: 5HTT and NPY positive<br>Outer core: PGP 9.5, 5HTT, 5HT1A, NSE<br>External capsule: PGP 9.5, nNOS<br>Stroma: VIP, NPY |
| Schober et al. 2015[5] | The tissue was stained, fixed, frozen, and cut into 30μm sections. The specimens were stained by Cajal-type silver impregnation and by immunocytochemistry against protein gene product (PGP) 9.5 and neuron-specific enolase (NSE). | Cajal-type Silver staining | Free nerve endings (FNE) found in the dermis were thin, mostly tortuous, branched or single processed, straight or bent. FNEs in epidermis terminated in the stratum granulosum; dense network of free endings was identified in the strata basale and spinosum. Neither FNE in the dermis or epidermis had associated connective tissue or Schwann cells. Pacinian corpuscles, with a central structure surrounded by an encapsulated stroma, and central axon surrounded by an inner core, outer core, and external capsule, protruded into the epidermis from the dermis. There were non-capsulated or Meissner-like corpuscles were scattered in the dermal papillae and interdigitated with the epidermal ridges of the skin, |
| | | PGP 9.5 | Schwann-related cells, perineurial-related cells, and terminal axons of the non-capsulated corpuscles in the dermis were positive for PGP 9.5. |
| | | NSE | Central axon and outer core of Pacinian corpuscles, as well as Schwann-related cells, perineurial-related cells, and terminal axons of the non-capsulated corpuscles in the dermis were positive for NSE |

**Table 3.** Summary of results from studies on the innervation of the labia minora. Abbreviations: NSE, neuron-specific enolase; PGP 9.5, protein gene product 9.5; VIP, vasoactive intestinal peptide; NPY, neuropeptide Y; nNOS, neuronal nitric oxide.

## References


1. Bajowa Edozien GY. Sexual Offenses, Adult: Normal Anogenital Anatomy and Variants. In: Payne-James J, Byard RW, eds. *Encyclopedia of Forensic and Legal Medicine (Second Edition)*. Elsevier; 2016:286-311. doi:10.1016/B978-0-12-800034-2.00074-4
2. Puppo V. Embryology and anatomy of the vulva: the female orgasm and women's sexual health. *Eur J Obstet Gynecol Reprod Biol*. 2011;154(1):3-8. doi:10.1016/j.ejogrb.2010.08.009
3. Sir E, Güngör M, Üçer O, Aksoy A. Evaluation of sexual function in women with labia minora hypertrophy: A preliminary study. *Rev Int Androl*. 2018;16(2):45-49. doi:10.1016/j.androl.2017.06.007
4. Shafik A, Shafik A a., Ahmed I. Response of the labia majora and minora to clitoral stimulation. *Int J Gynecol Obstet*. 2004;86(3):401-402. doi:10.1016/j.ijgo.2004.03.010
5. Schober J, Aardsma N, Mayoglou L, Pfaff D, Martín-Alguacil N. Terminal innervation of female genitalia, cutaneous sensory receptors of the epithelium of the labia minora. *Clin Anat*. 2015;28(3):392-398. doi:10.1002/ca.22502
6. Yang CC, Cold CJ, Yilmaz U, Maravilla KR. Sexually responsive vascular tissue of the vulva. *BJU Int*. 2006;97(4):766-772. doi:10.1111/j.1464-410X.2005.05961.x
7. Velikonja L, Giovannetti O, Adams MA, Tomalty D. Innervation of the human vulvar vestibule: A comprehensive review. *Clin Anat N Y N*. 2023;36(1):18-27. doi:10.1002/ca.23966
8. Tomalty D, Giovannetti O, Magliocchetti S, et al. Characterizing the innervation of the vulvar vestibule and the immunohistochemical features of neuroproliferative vestibulodynia. *J Sex Med*. 2023;20(6):716-731. doi:10.1093/jsxmed/qdad040
9. van Turnhout AA, Hage JJ, van Diest PJ. The female corpus spongiosum revisited. *Acta Obstet Gynecol Scand*. 1995;74(10):767-771. doi:10.3109/00016349509021194
10. Mazloomdoost D, Pauls RN. A Comprehensive Review of the Clitoris and Its Role in Female Sexual Function. *Sex Med Rev*. 2015;3(4):245-263. doi:10.1002/smrj.61
11. Lloyd J, Crouch NS, Minto CL, Liao LM, Creighton SM. Female genital appearance: "normality" unfolds. *BJOG Int J Obstet Gynaecol*. 2005;112(5):643-646. doi:10.1111/j.1471-0528.2004.00517.x
12. Peters MDJ, Marnie C, Tricco AC, et al. Updated methodological guidance for the conduct of scoping reviews. *JBI Evid Synth*. 2020;18(10):2119-2126. doi:10.11124/JBIES-20-00167
13. Tricco AC, Lillie E, Zarin W, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018;169(7):467-473. doi:10.7326/M18-0850
14. Ginger VAT, Cold CJ, Yang CC. Structure and innervation of the labia minora: more than minor skin folds. *Female Pelvic Med Reconstr Surg*. 2011;17(4):180-183. doi:10.1097/SPV.0b013e318221f835
15. Cao Y, Li F, Li S, Zhou Y, Li Q. A preliminary observational study on the vascular, nerve, and lymphatic anatomy and histology of the labia minora from cadaveric and surgical samples. *Int Urogynecology J*. 2021;32(5):1169-1176. doi:10.1007/s00192-020-04551-7
16. Ellibeş Kaya A, Doğan O, Yassa M, Başbuğ A, Özcan C, Çalışkan E. Do external female genital measurements affect genital perception and sexual function and orgasm? *Turk J Obstet Gynecol*. 2020;17(3):175-181. doi:10.4274/tjod.galenos.2020.89896
17. Suh DD, Yang CC, Cao Y, Heiman JR, Garland PA, Maravilla KR. MRI of female genital and pelvic organs during sexual arousal. *J Psychosom Obstet Gynaecol*. 2004;25(2):153-162. doi:10.1080/01674820400002220
18. Kaya AE, Dogan O, Yassa M, Basbug A, Çalışkan E. A Novel Technique for Mapping the Vascularity of Labia Minora Prior to Labiaplasty: Cold Light Illumination. *Geburtshilfe Frauenheilkd*. 2018;78(8):775-784. doi:10.1055/a-0647-2404

19. Battaglia C, Battaglia B, Busacchi P, Paradisi R, Meriggiola MC, Venturoli S. 2D and 3D Ultrasound Examination of Labia Minora. *Arch Sex Behav*. 2013;42(1):153-160. doi:10.1007/s10508-012-9899-5
20. Battaglia C, Battaglia B, Mancini F, et al. Cigarette smoking decreases the genital vascularization in young healthy, eumenorrheic women. *J Sex Med*. 2011;8(6):1717-1725. doi:10.1111/j.1743-6109.2011.02257.x
21. Libretti S, Aeddula NR. Embryology, Genitourinary. In: *StatPearls*. StatPearls Publishing; 2024. Accessed August 17, 2024. http://www.ncbi.nlm.nih.gov/books/NBK559309/
22. Yavagal S, de Farias TF, Medina CA, Takacs P. Normal Vulvovaginal, Perineal, and Pelvic Anatomy with Reconstructive Considerations. *Semin Plast Surg*. 2011;25(2):121-129. doi:10.1055/s-0031-1281481
23. Meriggiola MC, Villa P, Maffei S, et al. Vulvovaginal atrophy in women with and without a history of breast cancer: Baseline data from the PatiEnt satisfactiON studY (PEONY) in Italy. *Maturitas*. 2024;183:107950. doi:10.1016/j.maturitas.2024.107950
24. Farage M, Maibach H. Lifetime changes in the vulva and vagina. *Arch Gynecol Obstet*. 2006;273(4):195-202. doi:10.1007/s00404-005-0079-x
25. Hamori CA, Banwell PE, Alinsod R. *Female Cosmetic Genital Surgery: Concepts, Classification, and Techniques*. Thieme; 2017.
26. Motakef S, Rodriguez-Feliz J, Chung MT, Ingargiola MJ, Wong VW, Patel A. Vaginal labiaplasty: current practices and a simplified classification system for labial protrusion. *Plast Reconstr Surg*. 2015;135(3):774-788. doi:10.1097/PRS.0000000000001000
27. Elective Female Genital Cosmetic Surgery: ACOG Committee Opinion, Number 795. *Obstet Gynecol*. 2020;135(1):e36. doi:10.1097/AOG.0000000000003616
28. Gragasin FS, Michelakis ED, Hogan A, et al. The neurovascular mechanism of clitoral erection: nitric oxide and cGMP-stimulated activation of BKCa channels. *FASEB J Off Publ Fed Am Soc Exp Biol*. 2004;18(12):1382-1391. doi:10.1096/fj.04-1978com
29. Battaglia C, Battaglia B, Mancini F, et al. Sexual Behavior and Oral Contraception: A Pilot Study. *J Sex Med*. 2012;9(2):550-557. doi:10.1111/j.1743-6109.2011.02597.x
30. Helm KD, Nass RM, Evans WS. CHAPTER19 - Physiologic and Pathophysiologic Alterations of the Neuroendocrine Components of the Reproductive Axis. In: Strauss JF, Barbieri RL, eds. *Yen & Jaffe's Reproductive Endocrinology (Sixth Edition)*. W.B. Saunders; 2009:441-488. doi:10.1016/B978-1-4160-4907-4.00019-X
31. Cédrin-Durnerin I, Bständig B, Parneix I, et al. Effects of oral contraceptive, synthetic progestogen or natural estrogen pre-treatments on the hormonal profile and the antral follicle cohort before GnRH antagonist protocol. *Hum Reprod*. 2007;22(1):109-116. doi:10.1093/humrep/del340
32. Estrogens and Oral Contraceptives. In: *LiverTox: Clinical and Research Information on Drug-Induced Liver Injury*. National Institute of Diabetes and Digestive and Kidney Diseases; 2012. Accessed August 12, 2024. http://www.ncbi.nlm.nih.gov/books/NBK548539/
33. Jones EE. Androgenic effects of oral contraceptives: implications for patient compliance. *Am J Med*. 1995;98(1A):116S-119S. doi:10.1016/s0002-9343(99)80069-2
34. The effect of combined oral contraception on testosterone levels in healthy women: a systematic review and meta-analysis. In: *Database of Abstracts of Reviews of Effects (DARE): Quality-Assessed Reviews [Internet]*. Centre for Reviews and Dissemination (UK); 2014. Accessed August 12, 2024. https://www.ncbi.nlm.nih.gov/books/NBK164632/
35. Martin-Alguacil N, Pfaff DW, Kow LM, Schober JM. Oestrogen receptors and their relation to neural receptive tissue of the labia minora. *BJU Int*. 2008;101(11):1401-1406. doi:10.1111/j.1464-410X.2008.07626.x
36. Shih C, Cold CJ, Yang CC. The pars intermedia: an anatomic basis for a coordinated vascular response to female genital arousal. *J Sex Med*. 2013;10(6):1526-1530. doi:10.1111/j.1743-6109.2012.02996.x
37. Murina F, Fochesato C, Savasi VM. Treatment of Prepubertal Labial Adhesions with Topical Estriol + Testosterone: A Case Report. *Pediatr Rep*. 2024;16(3):558-565. doi:10.3390/pediatric16030047

38. Gonzalez D, Anand S, Mendez MD. Labial Adhesions. In: *StatPearls*. StatPearls Publishing; 2024. Accessed August 14, 2024. http://www.ncbi.nlm.nih.gov/books/NBK470461/
39. Hodgins MB, Spike RC, Mackie RM, MacLean AB. An immunohistochemical study of androgen, oestrogen and progesterone receptors in the vulva and vagina. *BJOG Int J Obstet Gynaecol*. 1998;105(2):216-222. doi:10.1111/j.1471-0528.1998.tb10056.x
40. Wilson AM, Zaki AA. Novel Clitoral Reconstruction and Coverage With Sensate Labial Flaps: Potential Remedy for Female Genital Mutilation. *Aesthet Surg J*. 2022;42(2):183-192. doi:10.1093/asj/sjab218
41. Jiang X, Chen S, Qu S, et al. A New Modified Labiaplasty Combined with Wedge De-Epithelialization on the Medial Side and Edge Resection. *Aesthetic Plast Surg*. 2021;45(4):1869-1876. doi:10.1007/s00266-021-02137-2
42. Georgiou CA, Benatar M, Dumas P, et al. A Cadaveric Study of the Arterial Blood Supply of the Labia Minora. *Plast Reconstr Surg*. 2015;136(1):167-178. doi:10.1097/PRS.0000000000001394
43. Ückert S, Oelke M, Albrecht K, Stief C, Jonas U, Hedlund P. Immunohistochemical description of cyclic nucleotide phosphodiesterase (PDE) isoenzymes in the human labia minora. *J Sex Med*. 2007;4(3):602-608. doi:10.1111/j.1743-6109.2007.00490.x
44. Schick MA, Schlegel N. Clinical Implication of Phosphodiesterase-4-Inhibition. *Int J Mol Sci*. 2022;23(3):1209. doi:10.3390/ijms23031209
45. Dhaliwal A, Gupta M. PDE5 Inhibitors. In: *StatPearls*. StatPearls Publishing; 2024. Accessed August 13, 2024. http://www.ncbi.nlm.nih.gov/books/NBK549843/
46. Tappy EE, Carrick KS, Ramirez DMO, Sawyer P, Corton MM. Anatomic relationships of the clitoral body, bulbs of the vestibule, and urethra. *Am J Obstet Gynecol*. 2023;228(6):720.e1-720.e8. doi:10.1016/j.ajog.2023.02.011
47. Alter GJ. Labia Minora Reduction Using Central Wedge Technique: Central Wedge Technique. *Clin Plast Surg*. 2022;49(4):447-453. doi:10.1016/j.cps.2022.06.002
48. Choi HY, Kim KT. A new method for aesthetic reduction of labia minora (the deepithelialized reduction of labioplasty). *Plast Reconstr Surg*. 2000;105(1):419-422; discussion 423-424. doi:10.1097/00006534-200001000-00067
49. Kelishadi SS, Omar R, Herring N, et al. The Safe Labiaplasty: A Study of Nerve Density in Labia Minora and Its Implications. *Aesthet Surg J*. 2016;36(6):705-709. doi:10.1093/asj/sjw002
50. Malinovský L, Sommerová J, Martincík J. Quantitative evaluation of sensory nerve endings in hypertrophy of labia minora pudendi in women. *Acta Anat (Basel)*. 1975;92(1):129-144.
51. Malinovský L, Sommerová J, Martinčík J. Quantitative evaluation of sensory nerve endings in hypertrophy of labia minora pudendi in women. *Acta Anat (Basel)*. 2008;92(1):129-144. doi:10.1159/000144435
52. Schober J, Cooney T, Pfaff D, Mayoglou L, Martin-Alguacil N. Innervation of the Labia Minora of Prepubertal Girls. *J Pediatr Adolesc Gynecol*. 2010;23(6):352-357. doi:10.1016/j.jpag.2010.03.009
53. Martín-Alguacil N, Aardsma N, Litvin Y, et al. Immunocytochemical Characterization of Pacinian-like Corpuscles in the Labia Minora of Prepubertal Girls. *J Pediatr Adolesc Gynecol*. 2011;24(6):353-358. doi:10.1016/j.jpag.2011.06.005
54. Payne KA, Binik YM, Pukall CF, Thaler L, Amsel R, Khalifé S. Effects of sexual arousal on genital and non-genital sensation: a comparison of women with vulvar vestibulitis syndrome and healthy controls. *Arch Sex Behav*. 2007;36(2):289-300. doi:10.1007/s10508-006-9089-4
55. Erol B, Tefekli A, Sanli O, et al. Does sexual dysfunction correlate with deterioration of somatic sensory system in diabetic women? *Int J Impot Res*. 2003;15(3):198-202. doi:10.1038/sj.ijir.3900998
56. Ghezzi A, Callea L, Zaffaroni M, Zibetti A, Montanini R. Perineal motor potentials to magnetic stimulation, pudendal evoked potentials and perineal reflex in women. *Neurophysiol Clin Clin Neurophysiol*. 1992;22(4):321-326. doi:10.1016/s0987-7053(05)80264-3
57. Payne JA, Alexander BT, Khalil RA. Reduced Endothelial Vascular Relaxation in Growth-Restricted Offspring of Pregnant Rats With Reduced Uterine Perfusion. *Hypertension*. 2003;42(4):768-774. doi:10.1161/01.HYP.0000084990.88147.0C

58. Chen W can, Liu Y bin, Liu W feng, Zhou Y ying, He H fan, Lin S. Neuropeptide Y Is an Immunomodulatory Factor: Direct and Indirect. *Front Immunol*. 2020;11. doi:10.3389/fimmu.2020.580378
59. Hodges GJ, Jackson DN, Mattar L, Johnson JM, Shoemaker JK. Neuropeptide Y and neurovascular control in skeletal muscle and skin. *Am J Physiol - Regul Integr Comp Physiol*. 2009;297(3):R546-R555. doi:10.1152/ajpregu.00157.2009
60. Anderson ZT, Dawson AD, Slominski AT, Harris ML. Current Insights Into the Role of Neuropeptide Y in Skin Physiology and Pathology. *Front Endocrinol*. 2022;13:838434. doi:10.3389/fendo.2022.838434
61. Delgado M, Ganea D. Vasoactive intestinal peptide: a neuropeptide with pleiotropic immune functions. *Amino Acids*. 2013;45(1):25-39. doi:10.1007/s00726-011-1184-8
62. Battaglia C, Battaglia B, Mancini F, Nappi RE, Paradisi R, Venturoli S. Moderate alcohol intake, genital vascularization, and sexuality in young, healthy, eumenorrheic women. A pilot study. *J Sex Med*. 2011;8(8):2334-2343. doi:10.1111/j.1743-6109.2011.02310.x
63. Battaglia C, Persico N, Zanetti I, et al. Morphometric and Vascular Modifications of the Clitoris During Pregnancy: A Longitudinal, Pilot Study. *Arch Sex Behav*. 2018;47(5):1497-1505. doi:10.1007/s10508-017-1046-x
64. Sommer F, Caspers HP, Esders K, Klotz T, Engelmann U. Measurement of vaginal and minor labial oxygen tension for the evaluation of female sexual function. *J Urol*. 2001;165(4):1181-1184.
65. García-Mesa Y, Cárcaba L, Coronado C, et al. Glans clitoris innervation: PIEZO2 and sexual mechanosensitivity. *J Anat*. 2021;238(2):446-454. doi:10.1111/joa.13317
66. Qi L, Iskols M, Greenberg RS, et al. Krause corpuscles are genital vibrotactile sensors for sexual behaviours. *Nature*. 2024;630(8018):926-934. doi:10.1038/s41586-024-07528-4
67. Wielicka M, Neubauer-Geryk J, Kozera G, Bieniaszewski L. Clinical application of pulsatility index. *Med Res J*. 2020;5(3):201-210. doi:10.5603/MRJ.a2020.0016
68. Kassab MY, Majid A, Farooq MU, et al. Transcranial Doppler: An Introduction for Primary Care Physicians. *J Am Board Fam Med*. 2007;20(1):65-71. doi:10.3122/jabfm.2007.01.060128
69. Martin RJ, Fanaroff AA, Walsh MC. *Fanaroff and Martin's Neonatal-Perinatal Medicine E-Book: Diseases of the Fetus and Infant*. Elsevier Health Sciences; 2014.
70. Denniston GC, Hodges FM, Milos MF. *Male and Female Circumcision: Medical, Legal, and Ethical Considerations in Pediatric Practice*. Springer Science & Business Media; 2007.
71. Shenoy S, Gopishyam M. Successful Treatment Outcome in a Woman with Congenital Adrenal Hyperplasia. *J Obstet Gynaecol India*. 2019;69(2):188-191. doi:10.1007/s13224-018-1193-6
72. Abosena W, Almetaher HA, El Attar AA, Nofal AH, Elhalaby EA. Outcomes of one-stage feminizing genitoplasty in children with congenital adrenal hyperplasia and severe virilization. *Pediatr Surg Int*. 2024;40(1):72. doi:10.1007/s00383-024-05638-8
73. Krege S, Walz K h., Hauffa B p., Körner I, Rübben H. Long-term follow-up of female patients with congenital adrenal hyperplasia from 21-hydroxylase deficiency, with special emphasis on the results of vaginoplasty. *BJU Int*. 2000;86(3):253-258. doi:10.1046/j.1464-410x.2000.00789.x