

How to Cite:

Mishra, J. V. (2021). Genetics of Pumsavana Karma: A comprehensive review. *International Journal of Health Sciences*, 5(S2), 1554–1563. Retrieved from <https://sciencescholar.us/journal/index.php/ijhs/article/view/15922>

Genetics of Pumsavana Karma: A comprehensive review

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Abstract---Background: Pumsavana Karma is one of the sixteen Shodasha Samskaras (sacraments) described in Ayurveda, performed during the second or third month of pregnancy with the primary intent of obtaining a male progeny. Modern genetics has revealed complex molecular mechanisms underlying sex determination, including the role of the SRY gene on the Y chromosome, hormonal pathways, and epigenetic factors. This review bridges classical Ayurvedic concepts of Pumsavana Karma with contemporary genetic and molecular biology perspectives. **Objective:** To systematically review the classical descriptions of Pumsavana Karma in Ayurvedic texts, analyze the underlying biological rationale, and correlate these ancient practices with modern understanding of genetics, epigenetics, sex determination, and reproductive biology. **Methods:** A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and classical Ayurvedic texts including Charaka Samhita, Sushruta Samhita, and Ashtanga Hridayam. Articles published between 1980 and 2025 related to sex determination genetics, Pumsavana, prenatal Samskaras, and Ayurvedic embryology were reviewed. **Conclusion:** While Pumsavana Karma's primary goal of sex selection lacks support under Mendelian genetics, several ingredients used in the procedure (e.g., Banyan tree shoot latex, herbal formulations) exhibit biologically active phytochemicals with documented effects on hormonal milieu, sperm function, and epigenetic regulation. The ritual timing aligns with critical windows of gonadal sex differentiation. Further randomized controlled trials and molecular studies are warranted.

Keywords---Pumsavana Karma, Sex determination, SRY gene, Epigenetics, Ayurvedic genetics, Prenatal Samskaras, Shodasha Samskaras, Phytochemicals, Sex differentiation, Garbhini Paricharya.

1. INTRODUCTION

Ayurveda, the ancient Indian system of medicine, encompasses an elaborate framework for prenatal care through a series of rituals and medical procedures collectively termed Garbhini Paricharya (antenatal care). Among these, the Shodasha Samskaras (sixteen sacraments) hold a prominent place in shaping the physical, psychological, and spiritual attributes of the developing fetus. Pumsavana Karma, the second among the prenatal Samskaras, is described in detail across major classical texts including Charaka Samhita (Sharirasthana 8/17), Sushruta Samhita (Sharirasthana 2/18), and Ashtanga Hridayam (Uttarasthana 1/5).

The term 'Pumsavana' is derived from Sanskrit: 'Pum' meaning male and 'Savana' meaning to impel or produce, thus literally meaning 'that which produces a male child.' Classically, this procedure is performed during the second or third month of pregnancy — a period that modern embryology identifies as coinciding with gonadal sex differentiation, a critical window during which testis-determining genes are activated in genetically male embryos.

With advances in molecular genetics, sex determination is now understood to be a tightly regulated cascade initiated by the Sex-determining Region Y (SRY) gene, followed by downstream activation of SOX9, AMH (Anti-Mullerian Hormone), and testosterone synthesis pathways. The question, therefore, arises: does Pumsavana Karma intersect with any of these genetic and molecular mechanisms? And if so, could the herbal ingredients, timing, and ritualistic practices hold any scientific validity?

This review critically examines the classical Ayurvedic descriptions of Pumsavana Karma, the pharmacological profile of ingredients used, and correlates them with modern understanding of sex genetics, epigenetics, and reproductive biology. The aim is neither to validate nor dismiss this ancient practice but to analyze it through the lens of contemporary biomedical science and open pathways for rigorous scientific inquiry.

2. HISTORICAL AND CLASSICAL BACKGROUND

2.1 Textual References

Pumsavana Karma finds mention across multiple classical Ayurvedic texts. Charaka Samhita (Sharirasthana 8/17) recommends instilling the juice of a young shoot (Ankura) of the Banyan tree (Vata, *Ficus benghalensis*) or a paste of Shveta Jiraka (white cumin, *Cuminum cyminum*) mixed with milk into the right nostril for a male child. Sushruta Samhita adds the use of Sahachara (*Strobilanthes ciliatus*) and recommends the procedure be performed under a Pushya Nakshatra (an auspicious lunar asterism), signifying the ritualistic and cosmobiological dimensions of the practice.

Ashtanga Hridayam by Vagbhata (Uttarasthana, Chapter 1) provides the most comprehensive description, advising that a woman who has confirmed pregnancy through nausea and other signs should be administered nasal drops (Nasya) of the freshly expressed juice of Banyan tree shoots mixed with the milk of a woman

who has borne male children. The text also describes Pumsavana as beneficial for the general wellbeing of the fetus, beyond mere sex determination.

Kashyapa Samhita, a specialized text on pediatrics and obstetrics, gives considerable importance to Pumsavana and describes additional formulations including Brahmi (*Bacopa monnieri*) and Shatavari (*Asparagus racemosus*) as ancillary medicines, hinting at their role in neurological development and hormonal balance.

2.2 Procedure and Timing

The procedure is traditionally performed in the second or third month of pregnancy, specifically on an auspicious day when the Pushya Nakshatra is ascendant, and under the guidance of a Vaidya (Ayurvedic physician). The key procedural steps include: (1) Purification of the mother through mild Panchakarma procedures; (2) Administration of Nasya (nasal instillation) of herbal preparations, predominantly Banyan tree shoot latex mixed with milk; (3) Accompanying Mantras (Vedic hymns) and rituals performed by the husband and a qualified priest; and (4) Dietary regulations (Pathya) including avoidance of sour, pungent foods and adoption of a Sattvic diet.

The timing of the procedure is particularly significant from a modern embryological standpoint. At 6–8 weeks of gestation (which aligns with the second month of lunar calendar-based pregnancy), the gonadal ridge begins differentiating into either testes or ovaries. The SRY gene on the Y chromosome must be expressed during this narrow window, making it a critical and sensitive period for sex determination.

3. GENETICS OF SEX DETERMINATION: A MODERN OVERVIEW

3.1 Chromosomal Sex Determination

In humans, chromosomal sex is established at fertilization. Spermatozoa carrying either the X or Y chromosome fertilize the ovum (always X-bearing), determining the chromosomal constitution as 46,XX (female) or 46,XY (male). This binary chromosomal system, as described by Sutton and Boveri (1902) and later confirmed by Tjio and Levan (1956), forms the foundation of Mendelian sex determination.

However, chromosomal sex is only the first step in a multi-layered process. Gonadal sex differentiation, hormone synthesis, and secondary sex characteristic development involve a cascade of gene expressions that can be influenced by both genetic and environmental factors. Importantly, approximately 1 in 5500 individuals are born with disorders of sex development (DSD), highlighting that the pathway from chromosomal to phenotypic sex is not always linear.

3.2 The SRY Gene and Testis Determination

The SRY (Sex-determining Region Y) gene, located on the short arm of the Y chromosome (Yp11.3), was identified by Sinclair et al. in 1990 as the testis-determining factor. SRY encodes a transcription factor of the HMG-box family that, when expressed in the bipotential gonad at approximately 6–7 weeks of gestation, activates SOX9 (SRY-box transcription factor 9) on chromosome 17.

SOX9 upregulation triggers a cascade: activation of FGF9 (Fibroblast Growth Factor 9), PTGDS (Prostaglandin D2 synthase), and AMH (Anti-Mullerian Hormone). This cascade leads to Sertoli cell differentiation, Mullerian duct regression, and eventual testosterone synthesis by Leydig cells — all essential for male development. In the absence of SRY expression, the bipotential gonad defaults to ovarian differentiation, driven by WNT4, RSPO1, and FOXL2.

3.3 Epigenetics and Sex Determination

Beyond genetic sequences, epigenetic modifications — heritable changes in gene expression without alterations in DNA sequence — play a pivotal role in sex determination and differentiation. DNA methylation, histone acetylation, and non-coding RNA-mediated regulation have all been demonstrated to influence gonadal gene expression. Notably, the expression of SRY itself is subject to epigenetic regulation; alterations in methylation patterns at the SRY promoter can influence its level of transcription.

The concept of epigenetic modulation of sex determination holds particular relevance for the Ayurvedic perspective, as phytochemicals are known potent epigenetic modulators. Several plant-derived compounds — including flavonoids, isoflavones, and terpenoids — found in classical Pumsavana formulations have been shown to alter DNA methylation patterns and histone modification status in reproductive cells.

3.4 Hormonal Influences on Sex Differentiation

The gonadal secretion of sex hormones critically governs phenotypic sex differentiation. Fetal testosterone, produced by Leydig cells under the influence of hCG (human Chorionic Gonadotropin) and later fetal LH, drives Wolffian duct differentiation into epididymis, vas deferens, and seminal vesicles. Simultaneously, AMH causes Mullerian duct regression. Disruption of these hormonal signals — as seen in congenital adrenal hyperplasia (CAH), androgen insensitivity syndrome (AIS), or 5-alpha reductase deficiency — results in DSD.

Environmental endocrine disruptors (EDCs), including certain plant-derived phytoestrogens, can interfere with these hormonal signals. The presence of phytoestrogenic and androgenic compounds in Pumsavana herbs thus warrants careful evaluation in the context of their potential to modulate the hormonal milieu of early gestation.

4. PHARMACOLOGICAL AND GENETIC ANALYSIS OF PUMSAVANA INGREDIENTS

4.1 *Ficus benghalensis* (Vata/Banyan Tree)

The primary ingredient in Pumsavana Karma is the fresh juice or latex of a Banyan tree shoot (Vata ankura). *Ficus benghalensis* has been extensively studied for its pharmacological properties. The latex contains leucocyanidin, bengalenoside, friedelin, and various flavonoids. Of particular significance is its content of phytosterols, including beta-sitosterol and stigmasterol, which are structural analogues of cholesterol and serve as precursors for steroid hormone biosynthesis.

Research has demonstrated that beta-sitosterol can competitively inhibit the enzyme 5-alpha reductase, which converts testosterone to dihydrotestosterone

(DHT). Additionally, studies using cell lines have shown that *Ficus benghalensis* leaf extract can modulate androgen receptor (AR) activity. The AR gene, located on chromosome Xq11-12, encodes the intracellular receptor for testosterone and DHT; its expression and sensitivity are critical for male sex differentiation. Whether Banyan latex, when administered nasally, can achieve systemic concentrations capable of modulating fetal gonadal hormone activity remains to be elucidated.

4.2 *Cuminum cyminum* (Shveta Jiraka/White Cumin)

Shveta Jiraka (*Cuminum cyminum* L., Apiaceae) is another frequently cited ingredient in Pumsavana formulations. Its active phytochemicals include cuminaldehyde, cymene, terpene compounds, and flavonoids. Modern studies have demonstrated anti-inflammatory, anti-oxidant, and phytoestrogenic properties. The isoflavone content is particularly relevant, as isoflavones are known to interact with estrogen receptors (ER α and ER β) encoded by ESR1 (chromosome 6q25.1) and ESR2 (chromosome 14q23.2) genes respectively.

In the context of Pumsavana Karma, the phytoestrogenic effects of cumin derivatives could theoretically modulate the balance between androgen and estrogen signaling in the early embryo. However, this is a double-edged sword: excessive phytoestrogen exposure during the critical window of male sex differentiation could potentially impair masculinization rather than promote it, as demonstrated in animal studies with genistein (a soy isoflavone).

4.3 *Asparagus racemosus* (Shatavari)

Shatavari (*Asparagus racemosus* Wild., Asparagaceae), though mentioned more in adjunct formulations, deserves mention for its steroidal saponins — Shatavarins I–IV. These saponins have demonstrated LH-like activity in animal models and have been shown to augment follicular steroidogenesis. In male reproductive physiology, LH is essential for Leydig cell stimulation and testosterone synthesis. The LH receptor gene (LHCGR, chromosome 2p21) encodes both LH and hCG receptors, and its activation is crucial for early fetal testosterone production.

Shatavari has also been studied for its adaptogenic properties and ability to reduce oxidative stress in reproductive tissues. Given that reactive oxygen species (ROS) can damage sperm DNA and impair spermatogenesis — processes governed by a host of genes including DAZL, SYCP3, and TEX11 — the antioxidant role of Shatavari could be extrapolated to preconceptional sperm quality, though this is distinct from Pumsavana Karma's pregnancy application.

4.4 *Bacopa monnieri* (Brahmi)

Brahmi (*Bacopa monnieri* L., Plantaginaceae) is cited in the Kashyapa Samhita as an adjunct to Pumsavana Karma. Its major active constituents — bacosides A and B — have demonstrated neuroprotective, antioxidant, and nootropic properties. Of relevance to sex differentiation is Brahmi's documented ability to modulate the hypothalamic-pituitary-gonadal (HPG) axis in animal models. Bacosides have been shown to influence GnRH (Gonadotropin-Releasing Hormone) pulsatility and LH secretion, indirectly affecting gonadal steroidogenesis.

More recently, studies have investigated Brahmi's role as an epigenetic modulator. Bacoside A has been shown to inhibit histone deacetylases (HDACs) and alter DNA methylation patterns in neural tissue. Its potential to similarly

modulate epigenetic marks in gonadal tissue during the critical window of sex differentiation opens an intriguing line of investigation.

4.5 Human Milk (from a Mother of Male Children)

The classical prescription of using milk from a woman who has borne male children introduces a fascinating dimension: bioactive factors in human milk. Human milk contains a spectrum of growth factors, cytokines, hormones, and microRNAs (miRNAs). Notably, human milk has been shown to contain testosterone and other androgens, particularly in the colostrum and early lactation phases, with milk from mothers of male infants showing higher androgen concentrations than from mothers of female infants.

MicroRNAs in human milk are particularly significant from a genetic standpoint. Exosomal miRNAs in milk are stable, cell-permeable, and capable of crossing mucosal barriers. If absorbed nasally, these miRNAs could potentially interact with target genes involved in sex determination or gonadal differentiation. miR-21, miR-146a, and miR-155, commonly found in human milk, have documented roles in regulating TGF-beta signaling, a pathway with known roles in gonadal differentiation and Sertoli cell function.

5. CONCEPTUAL CORRELATION: AYURVEDIC GENETICS AND MODERN MOLECULAR BIOLOGY

5.1 Prakriti, Beeja, and the Genetics of the Individual

Classical Ayurvedic embryology, as described in Charaka Samhita (Sharirasthana 3), attributes the formation of an individual to Shad Garbhakara Bhavas (six factors contributing to the embryo): Matrija (maternal), Pitrija (paternal), Atmaja (self/soul), Satmyaja (habituation), Rasaja (nutrition), and Sattvaja (psychological). The Pitrija and Matrija components directly correlate with paternal (spermatozoon) and maternal (ovum) genetic contributions, as recognized in modern Mendelian genetics.

The concept of Beeja (seed, referring to germ cells) and Beejabhaga (part of the seed) in Ayurveda has been interpreted as corresponding to chromosomes and individual genes respectively. Sushruta (Sharirasthana 2/33) states that the sex of the progeny is determined by the Beejabhagavayava (sub-components of the seed) — a remarkably prescient observation that aligns with the Y-chromosome-borne SRY gene governing male sex determination.

5.2 Timing Correlation: Pumsavana and the Window of Sex Determination

Perhaps the most compelling correlation between Pumsavana Karma and modern genetics lies in its timing. Classical texts unanimously recommend performing this sacrament in the second or third lunar month of pregnancy (approximately 8–12 weeks of gestation in the modern calendar). This corresponds precisely to the critical window of gonadal sex differentiation (6–9 weeks) and the beginning of genital development (9–12 weeks).

The Pumsavana procedure could be conceptualized as an attempt to modulate the hormonal and molecular environment during this critical period — essentially attempting to shift the developmental trajectory toward male phenotype by enhancing androgen signaling, stimulating SRY-dependent pathways, or providing biological factors (hormones, growth factors, miRNAs) that favor testicular differentiation. While modern genetics establishes that chromosomal

sex is irreversibly determined at fertilization, phenotypic sex differentiation remains a dynamic process susceptible to environmental and molecular influences.

5.3 The Nasal Route: Pharmacokinetic Considerations

The Nasya (nasal administration) route prescribed for Pumsavana Karma is of particular scientific interest. The nasal mucosa is highly vascularized, and certain substances administered intranasally can bypass the blood-brain barrier via the olfactory nerve pathway, achieving direct access to the central nervous system. The hypothalamus — the master regulator of the HPG axis — is thus directly accessible via nasal administration.

If the bioactive phytochemicals in Banyan latex or other Pumsavana preparations reach the hypothalamus, they could theoretically modulate GnRH secretion, which governs fetal LH and hCG production, ultimately influencing gonadal steroidogenesis and sex differentiation. This proposed mechanism, while speculative, is consistent with the pharmacokinetic advantages of the nasal route documented in modern drug delivery research.

6. CRITICAL APPRAISAL: LIMITATIONS AND ETHICAL CONSIDERATIONS

6.1 Limitations of the Ayurvedic Claim

The primary claim of Pumsavana Karma — that it can determine or influence the sex of an unborn child toward maleness — is not supported by modern genetic principles. Chromosomal sex is determined at fertilization; once a zygote carries XX or XY chromosomes, no postnatal or early prenatal intervention can alter this fundamental genetic constitution. The assertion that nasal instillation of herbal preparations in the second or third month can change chromosomal sex is therefore biologically untenable under current understanding.

However, reducing Pumsavana Karma solely to a sex-selection procedure undervalues its broader textual mandate. Classical texts also describe Pumsavana as Garbha Sthirikaran (stabilizing the embryo), promoting fetal health, preventing miscarriage, and supporting optimal neurological development — goals that are entirely consistent with modern antenatal care principles. In this sense, the procedure may have genuine therapeutic value independent of its sex-determination claims.

6.2 Ethical and Legal Considerations

In India, sex-selective practices are governed by the Pre-conception and Pre-natal Diagnostic Techniques (PCPNDT) Act, 1994, which prohibits sex determination and sex-selective abortion. Any attempt to revive or promote Pumsavana Karma specifically for sex selection purposes would be ethically problematic and legally contentious in this context. The demographic consequences of son-preference practices in South Asia — including skewed sex ratios and gender-based violence — further underscore the need for responsible representation of these practices.

Academic and clinical interest in Pumsavana Karma should therefore focus on its pharmacological, nutritional, and psychosomatic benefits rather than on its sex-determination claims. Reframing Pumsavana as a 'prenatal wellness Samskara' — with emphasis on the Sattvic diet, maternal psychological wellbeing, herbal immunomodulation, and ritual stress reduction — would align better with both modern evidence and contemporary ethical standards.

6.3 Research Gaps

Despite substantial classical literature on Pumsavana Karma, there is a striking paucity of modern experimental and clinical research. Systematic reviews have identified fewer than a dozen peer-reviewed studies specifically addressing Pumsavana Karma, and most are observational or descriptive. Key research gaps include: the bioavailability of active compounds from Nasya preparations; the in vivo effects of Banyan latex phytochemicals on gonadal gene expression; the miRNA profile of human milk from mothers of male versus female children; and randomized controlled trials assessing the prenatal safety and efficacy of Pumsavana formulations.

7. DISCUSSION

This review has attempted to examine Pumsavana Karma through the lens of modern genetics and molecular biology, highlighting areas of convergence, divergence, and open questions. The central genetic principle that chromosomal sex is immutably determined at fertilization by the presence or absence of the Y chromosome remains uncontested. However, the broader biological environment of early gestation — including hormonal milieu, epigenetic programming, maternal immune status, and nutritional adequacy — does influence fetal sex differentiation and overall health outcomes in ways that may be amenable to intervention.

Several ingredients of classical Pumsavana formulations have demonstrated pharmacologically relevant activities: phytosterols in *Ficus benghalensis* modulate androgen signaling; isoflavones in *Cuminum cyminum* interact with estrogen receptors; steroidal saponins in *Asparagus racemosus* exhibit LH-like activity; and bacosides in *Bacopa monnieri* exhibit epigenetic modulatory effects. The convergence of these activities with the molecular pathways of sex differentiation, while circumstantial, warrants systematic investigation.

The nasal route of administration adds another dimension of plausibility, given its documented utility in delivering neurologically and endocrinologically active compounds. The theoretical pathway from nasal Nasya administration to hypothalamic modulation, altered GnRH pulsatility, modified fetal LH secretion, and ultimately influenced gonadal steroidogenesis constitutes a scientifically coherent (though unverified) chain of events.

The timing of Pumsavana Karma, coinciding with the critical window of gonadal sex differentiation, further suggests that ancient Ayurvedic practitioners possessed empirical knowledge — derived through generations of systematic observation — of the developmental sensitivity of this period. Whether this timing was based on conscious understanding of fetal development or arose through cultural transmission of observed outcomes remains unclear, but it represents a remarkable convergence with modern embryology.

Future research should employ contemporary tools including transcriptomics, epigenomics, and metabolomics to characterize the molecular effects of Pumsavana preparations on relevant cell lines and animal models. Phase I/II clinical trials focusing on safety and general prenatal wellness outcomes

(maternal anxiety, fetal growth, neonatal health) — rather than sex selection — would provide valuable evidence for or against the integration of Pumsavana practices into modern antenatal care.

8. CONCLUSION

Pumsavana Karma, one of the most ancient and culturally significant prenatal rituals in Ayurveda, presents a complex interface between traditional knowledge and modern biomedical science. While its primary stated goal of sex selection of a male child is not supportable under Mendelian genetics — chromosomal sex being irreversibly determined at fertilization — several of its components and practices demonstrate biological plausibility in the broader context of reproductive health, prenatal wellness, and epigenetic modulation of sex differentiation.

The pharmacological activities of *Ficus benghalensis* (androgenic modulation), *Cuminum cyminum* (phytoestrogenic effects), *Asparagus racemosus* (gonadotropin-like activity), and *Bacopa monnieri* (epigenetic modulation and HPG axis regulation) collectively represent a sophisticated herbal ensemble that may influence the hormonal and molecular environment of early gestation. The nasal route of administration offers theoretical advantages in accessing the hypothalamic-pituitary axis. The timing of the procedure aligns with the critical window of gonadal sex differentiation.

This review advocates for a reframing of Pumsavana Karma within the modern scientific discourse: moving away from the contested and ethically problematic claim of sex selection toward a rigorous investigation of its pharmacological, nutritional, epigenetic, and psychosomatic effects on maternal and fetal wellbeing. Integration of classical Ayurvedic wisdom with modern genetic and molecular biology tools holds the promise of yielding novel prenatal interventions that are culturally resonant, scientifically valid, and therapeutically beneficial.

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