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Research Article

A CROSS-SECTIONAL SURVEY TO STUDY THE ASSOCIATION BETWEEN ENDOCRINE-DISRUPTING CHEMICALS AND EARLY PUBERTY IN GIRLS WSR TO *DUSHI VISHA*

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ABSTRACT

The onset of early puberty in girls has been reported globally, and its underlying causes remain largely unclear. While nutrition and obesity are recognized factors, exposure to environmental chemicals, particularly EDCs, is increasingly being explored as a potential contributor. **Objective:** To investigate the association between EDC exposure and early puberty using a survey-based approach to assess lifestyle, environmental exposures, and pubertal milestones among children and adolescents and compare with the concept of *Dushi visha*. **Methods:** A cross-sectional survey study was conducted to assess the impact of endocrine-disrupting chemicals (EDCs) on early puberty, with reference to the Ayurvedic concept of *Dushi Visha* using structured and validated questionnaire. **Results:** The study revealed most of the participants had frequent exposure to various EDCs through different pathways. The findings revealed that 3% of the participants had early puberty, and the mean age at menarche was 11.75 years. **Conclusion**: The study revealed lower mean age at menarche compared to reported national and global average and the sources of EDC exposure among the study participants were identified in the study. The findings support a potential parallel with the Ayurvedic concept of *Dushi Visha* as a model of cumulative toxicity.

INTRODUCTION

Puberty is a complex developmental transition marked by the appearance of secondary sexual characteristics, accelerated growth, and profound physical and psychological changes that culminate in reproductive maturity. The onset and progression of puberty is influenced by a combination of intrinsic factors (genetics) and extrinsic factors (environmental and nutritional influences). The activation of the Hypothalamic-Pituitary-Gonadal axis also plays a pivotal role in puberty changes.

Precocious puberty is defined as the onset of secondary sexual characteristics before age 8 in girls. It is broadly classified into 2 categories: Central precocious puberty (gonadotropin-dependent) and Peripheral precocious puberty (gonadotropin-independent). In recent decades, puberty has started earlier, especially in girls, likely due to increasing childhood obesity and environmental factors.[1] A study conducted recently demonstrated that a majority of women (66.2%) attained menarche between the ages of 13–14 years in India.[2]

Among the environmental factors, Endocrine disruptors have emerged as a strong contributor that impact pubertal timing. Endocrine Disrupting Chemical (EDCs) is defined as "exogenous agent that interferes with synthesis, secretion, transport, metabolism, binding action, or elimination of natural blood-borne hormones that are present in the body and are responsible for homeostasis, reproduction, and developmental process.[3] These chemicals act by imitating or blocking hormone signalling through the relevant hormonal receptors.[4]

EDCs, commonly found in plastics, personal care products, pesticides, and industrial pollutants, can interfere with hormonal regulation. They affect puberty by acting both peripherally on target organs, such as adipose tissue or adrenal glands, and/or

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centrally on the hypothalamic-pituitary-gonadal (HPG) axis.[5] They are hormonally active substances which can act as either agonists of estrogen receptors (ERs) or antagonists of androgen receptors (ARs), mimicking naturally occurring hormones.[6]

In recent decades, a trend of earlier pubertal onset has been observed globally.[7] Although factors such as nutrition and obesity are known contributors, increasing evidence suggests that environmental exposure to EDCs plays a significant role in accelerating the maturation of secondary sexual characteristics.[8]

The EDCs most extensively studied in regards to puberty include: Bisphenol A (BPA), phthalate esters, pesticides (dichloro-diphenyl, trichloroethane, pyrethroids), dioxins, polychlorinated biphenyls (PCBs), flame retardants (polybrominated biphenyls [PBB], polybrominated diphenyl ethers [PBDEs], fungicides (vinclozolin), pharmaceutical agents, e.g., diethyl stilbestrol.[8]

The constant exposure to such toxins in the environment over a period of time, its accumulation leads to toxicity in human body causing various ailments. This concept of cumulative toxicity is dealt as *Dushi visha* in Ayurveda. Any poison which has not eliminated completely from the body or partially nullified becomes weak and is called *Dushi Visha*. It does not cause immediate fatality because of its mild potency and encapsulated by *Kapha* stays inside the body for a long time. *Dushi visha* targeting individual *Dhatus* also manifest disorders of that particular *Dhatu*.[9]

Endocrine-disrupting chemicals (EDCs) that result in hormonal disruption and manifestation of different diseases could be related to *"Dushi Visha"*. Despite growing global evidence, there is a scarcity of region-specific studies exploring the association between EDC exposure and early puberty in the Indian context.

Considering increasing environmental pollution and lifestyle changes, it is essential to investigate local risk factors contributing to early pubertal onset in girls.

Therefore, the present study was undertaken to assess the association between exposure to endocrine-disrupting chemicals and early puberty in girls, with special reference to the Ayurvedic concept of *Dushi Visha*. The findings of this study may contribute to improved awareness, preventive strategies, and integration of traditional and modern perspectives in addressing emerging public health concerns.

Objectives

To identify the major sources of exposure to endocrine-disrupting chemicals (EDCs) in the study population, to determine the prevalence of early puberty among female children exposed to these chemicals, and to analyse the potential correlation between the level of EDC exposure and variations in the onset of puberty. Additionally, the study aims to review and interpret the Ayurvedic concept of *Dushi Visha* in the context of cumulative toxicity through an analysis of available classical and contemporary literature.

MATERIALS AND METHODS

Study Design

A cross-sectional survey study was conducted to assess the impact of endocrine-disrupting chemicals (EDCs) on early puberty using a structured questionnaire The questionnaire was developed based on literature review and classical Ayurvedic references on *Dushi Visha*. Face and content validity were established through expert evaluation. Content Validity Index (CVI) was calculated for each item. Reliability was tested using test–retest method. The participants were given the questionnaire and explained about the research and the responses were collected.

Study Population

Target population: School-aged girl children and adolescents between 6-15 years age.

Inclusion & Exclusion Criteria

School-aged girl children and adolescents between 6-15 years age. Children with prolonged exposure to potential EDC sources (plastics, pesticides, cosmetics, etc.). Children with genetic disorders or chronic illnesses affecting puberty and those on long-term hormonal therapy were excluded.

Operational Definition of Early Puberty: For the present study, early puberty was operationally defined based on clinical indicators including age at onset of menarche and Tanner staging. Early menarche was considered when the onset of menstruation occurred at the age of 9 years. Additionally, early development of secondary sexual characteristics, such as breast development (Tanner stage II or above) occurring earlier than the expected age norms, was also considered indicative of early pubertal onset.

Sample Size Calculation

The sample size for this cross-sectional study is calculated using the standard formula for estimating a proportion.

$$n = \frac{Z^2 \times p \times q}{d^2}$$

Sample Size: A total of 500 participants were included to enhance the overall validity, accuracy, and interpretability of the study outcomes.

Sampling Method: Stratified random sampling to ensure representation across different socio-economic and geographic backgrounds.

Structure of questionnaire: The questionnaire was divided into two sections. Section A comprised of details regarding demographic constitution, pubertal milestones, lifestyle factors including diet and nutrition, environmental factors- exposure to EDCs through various sources. The common EDCs considered for the study are Bisphenol A (BPA), phthalates, triclosan, parabens, formaldehyde, lead, Monosodium glutamate (MSG). Section B was based on the clinical and biochemical assessments: Anthropometric measurements: Height, weight, BMI and Tanner staging was used for puberty assessment. the findings were correlated to *Dushi visha lakshanas*.

Data collection

Permission from the concerned head of the institutes of selected schools were priorly procured by in-person visit and online communication from the institute as well to conduct survey. The content and aim of the study were verbally explained by the researcher to the participants, teachers as well. Participants doubts were cleared and consent was obtained. The questionnaire was given individually and data was gathered as filled forms.

Table 1: EDC Exposure Scoring System

Total EDC Score	Exposure Category
≤ 25	Low EDC Exposure
> 25	High EDC Exposure

An EDC exposure score was developed based on responses to questionnaire items related to potential sources of endocrine-disrupting chemicals. Each exposure variable was assigned a score of 1 for "Yes" and 0 for "No." The individual scores were summed to obtain a total EDC exposure score for each participant. Based on the total score, participants were categorized into two groups: low exposure (score ≤25) and high exposure (score >25).

Statistical Analysis: The data collected from the questionnaire and clinical assessment entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) version 26. Data cleaning and validation performed prior to analysis to ensure accuracy and completeness.

Descriptive statistics used to summarize the baseline characteristics of the study population. Categorical variables such as residence, dietary habits, environmental exposures, use of personal care products, and presence of early puberty expressed as frequencies and percentages. Continuous variables including age, age at menarche, height, weight, and body mass index (BMI) presented as mean and standard deviation (mean ± SD)

The prevalence of early puberty among the study participants calculated as a proportion with corresponding 95% confidence intervals. Exposure to endocrine-disrupting chemicals (EDCs) assessed using responses from the questionnaire, and where applicable, an exposure score was constructed to categorize participants into low and high exposure groups.

Inferential statistical tests applied to examine associations between EDC exposure and early puberty. Chi-square test used to determine the association between categorical variables such as levels of EDC exposure and pubertal status. A p-value of less than 0.05 will be considered statistically significant

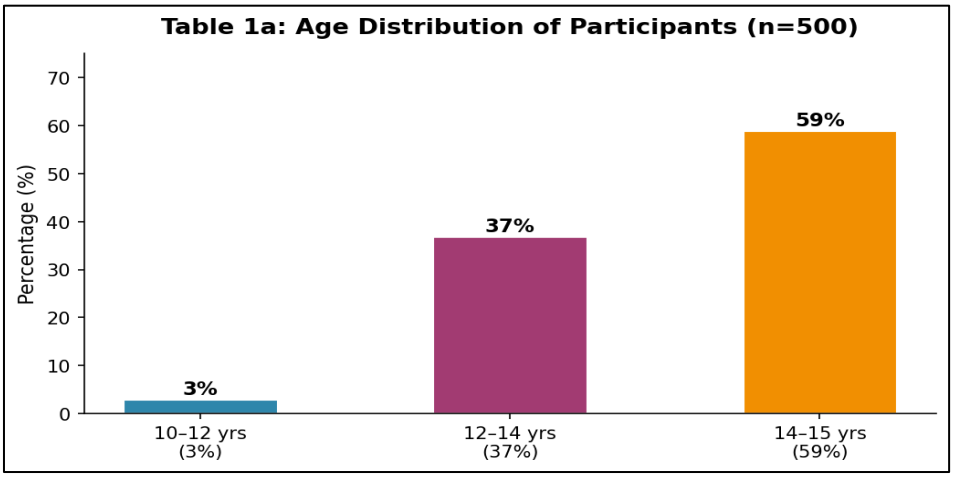
RESULTS

1a. Incidence of age: Age wise distribution of 500 participants shows that 3% participants were belonging to the age group 10-12 years, 37% of 12-14 years and 59% of 14-15 years and no participants were from 6-9 years.

Table 1a: Incidence of Age

Variable	Category	Frequency (n)	Percentage (%)
Age group	10-12 yrs	17	3%
	12-14 yrs	186	37%
	14-15	297	59%

Figure 1a: Incidence of Age

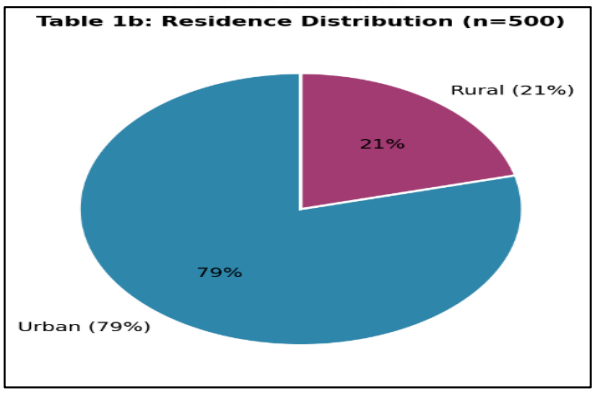


1b. Residence: Residential status of 500 participants shows that 79% were belong to urban and 21% belong to rural.

Table 1b: Residence

Variable	Category	Frequency (n)	Percentage (%)
Residence	Urban	397	79%
	Rural	103	21%

Figure 1b: Residence

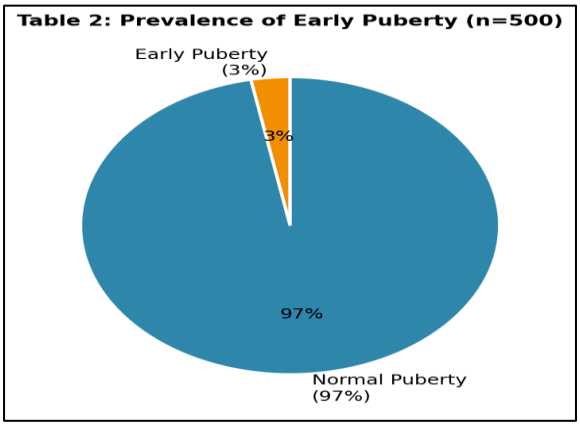


Prevalence of early puberty: Out of 500 participants, early puberty was identified in 3% and 97% identified as normal puberty.

Table 2: Prevalence of early puberty

Puberty Status	Frequency (n)	Percentage (%)
Early puberty present	14	3%
Normal puberty	486	97%

Figure 2: Prevalence of early puberty

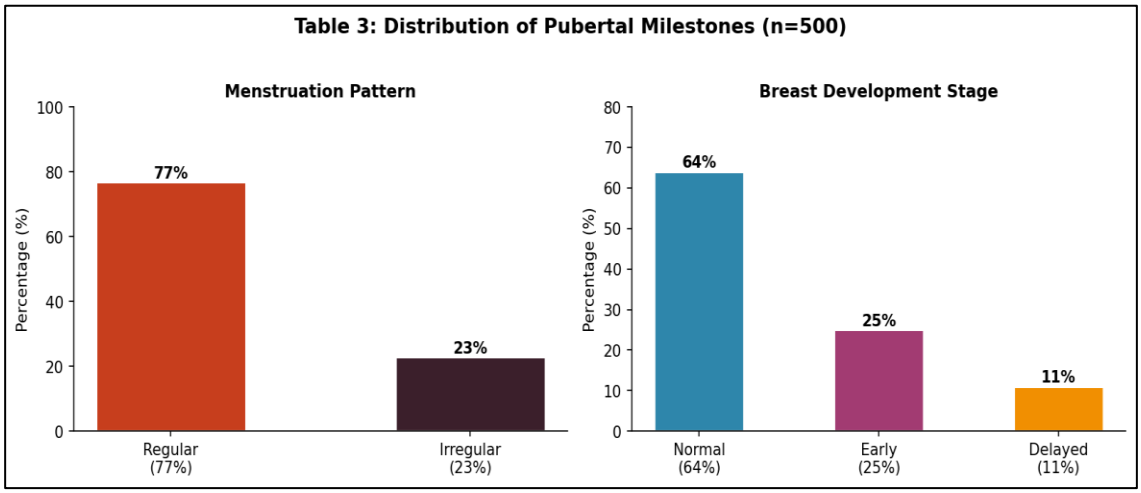


Distribution of pubertal milestones: Out of 500 participants, distribution of pubertal milestones shows that 77% of the participants had regular menstruation and 23% of them had irregular menstruation. Breast developmental features according to their age shows that 64% of the participants had normal breast development, 25% had early breast development and 11% of them had delayed breast development. Growth of pubic hair and axillary hair according to their age shows that 23% of participants had either pubic or axillary hair growth and 77% of them had both pubic and axillary hair growth.

Table 3: Distribution of pubertal milestones

Variable		Mean ± SD / Frequency	Percentage (%)
Age at menarche (years)		11.746±1.154	
Regular menstruation		383	77%
Irregular menstruation		117	23%
Breast development	Normal	319	64%
	Early	124	25%
	Delayed	57	11%
Development of either pubic hair and axillary hair		116	23%
Development of both pubic hair and axillary hair		384	77%

Figure 3: Distribution of pubertal milestones

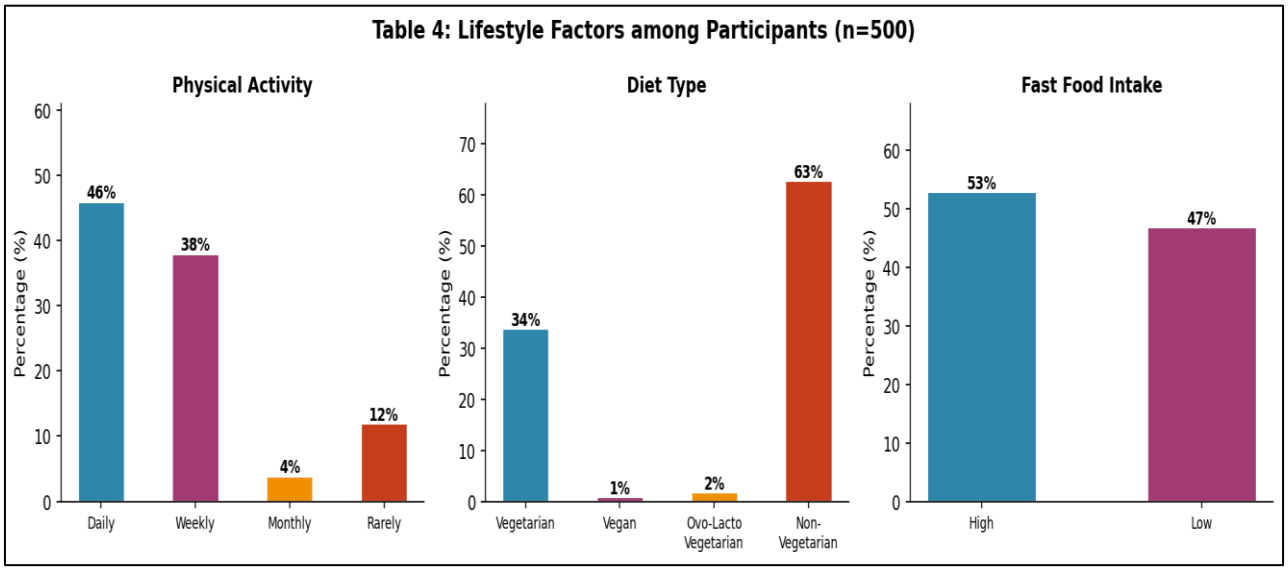


Lifestyle factors: Out of 500 participants, physical activity shows that 46% of the participants are doing physical activity every day, 38% are doing once in a week, 4% are doing once in a month and 12% are doing it rarely. Diet type shows that 34% of the participants are vegetarian,1% are vegan, 2% are ovo-Lacto vegetarian and 63% are non-vegetarians. Fast food intake shows that 53% of the participant's fast-food consumption is high and 47% of the participant's fast-food consumption is less.

Table 4: Lifestyle factors

Variable	Category	Frequency (n)	Percentage (%)
Physical activity	Daily	230	46%
	Weekly	191	38%
	Monthly	20	4%
	Rarely	59	12%
Diet type	Vegetarian	171	34%
	Vegan	4	1%
	Ovo-lacto vegetarian	8	2%
	Non-vegetarian	317	63%
Fast food intake	High	267	53%
	Low	233	47%

Figure 4: Lifestyle factors

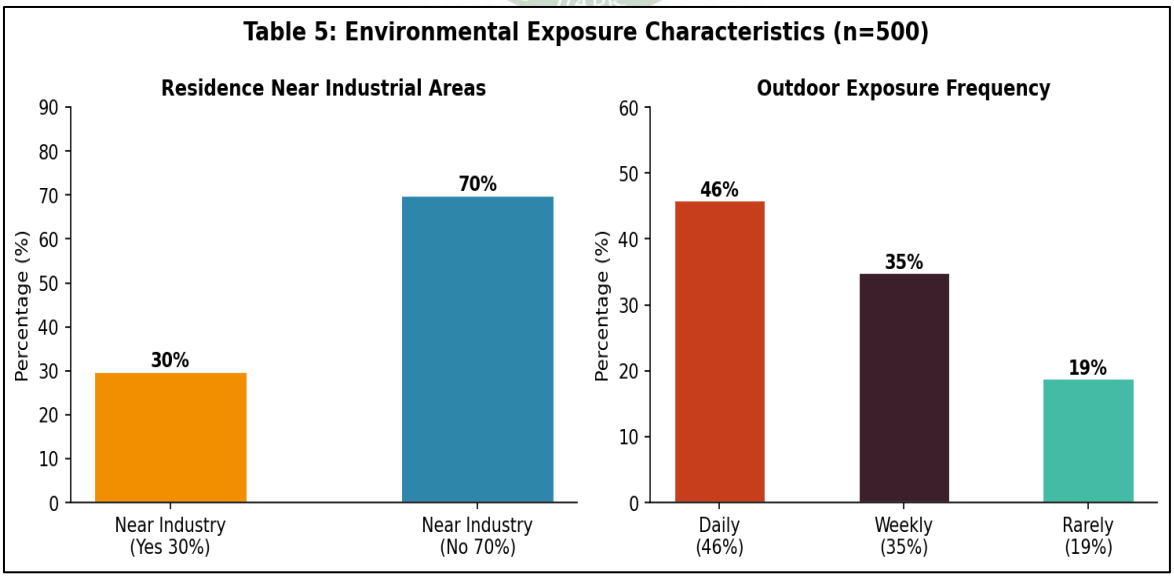


Environmental exposure characteristics: Out of 500 participants, residential area shows that 151 participants (30%) lived near industries, highways, factories and airports and 349 participants (70%) did not live near industries, highways, factories and airports. Outdoor exposure shows that 46% of the participants are exposing daily, 35% once in a week and 19% rarely.

Table 5: Environmental exposure characteristics

Variable	Category	Frequency (n)	Percentage (%)
Residence near industry, highways, factories or airports.	Yes	151	30%
	No	349	70%
Outdoor exposure	Daily	231	46%
	Weekly	176	35%
	Rarely	93	19%

Figure 5: Environmental exposure characteristics

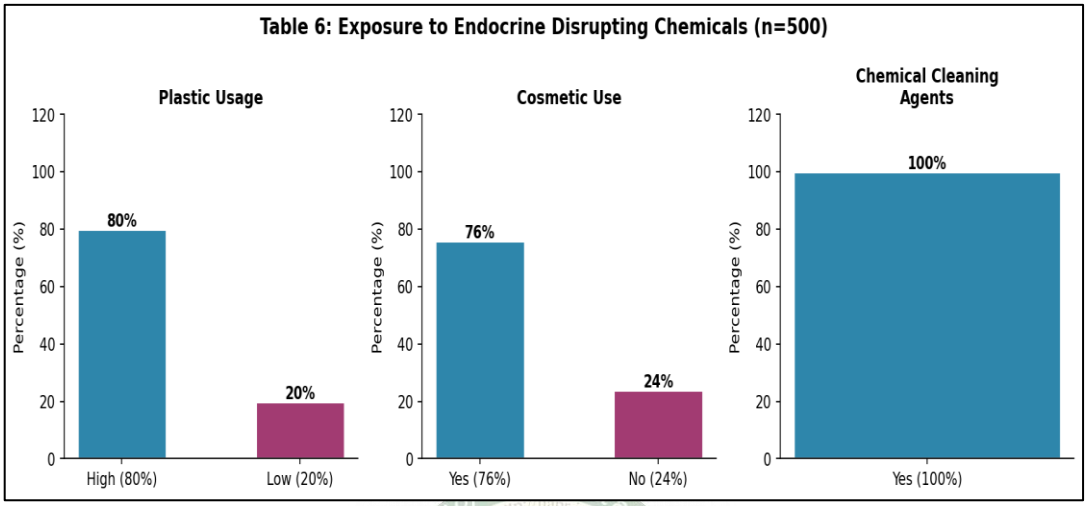


Exposure to Endocrine disrupting chemicals (EDC's): Out of 500 participants, plastic usage shows that 80% of the participants are consuming plastic packed foods and items in high amount and 20% of the participants are consuming plastic packed foods and items in less amount. Cosmetic usage shows that 76% of the participants are using cosmetics and 24% of the participants are not using cosmetics. Use of chemical agents shows that 100% of the participants are using chemical agent.

Table 6: Exposure to EDC's

Exposure Source	Category	Frequency (n)	Percentage (%)
Plastic usage	High	401	80%
	Low	99	20%
Cosmetic use	Yes	380	76%
	No	120	24%
Use of chemical cleaning agents	Yes	500	100%

Figure 6: Exposure to EDCs

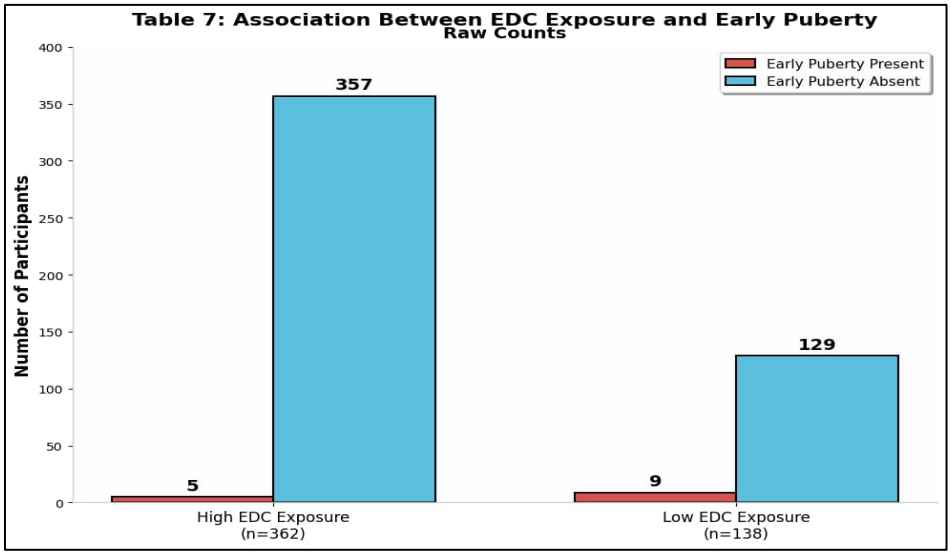


Association between EDC exposure and early puberty: Out of 500 participants, high exposure to EDC are 362 participants and low exposure to EDC are 138 participants. High exposure to EDC shows that 5 of the participants had early menarche and 357 participants didn't. Low exposure to EDC shows that 9 of the participants had early menarche and 129 didn't.

Table 7: Association between EDC exposure and early puberty

EDC Exposure	Early Puberty Present n (%)	Early Puberty Absent n (%)	p-value
High exposure (n=362)	5	357	<0.001
Low exposure (n=138)	9	129	<0.001

Figure 7: Association between EDC exposure and early puberty

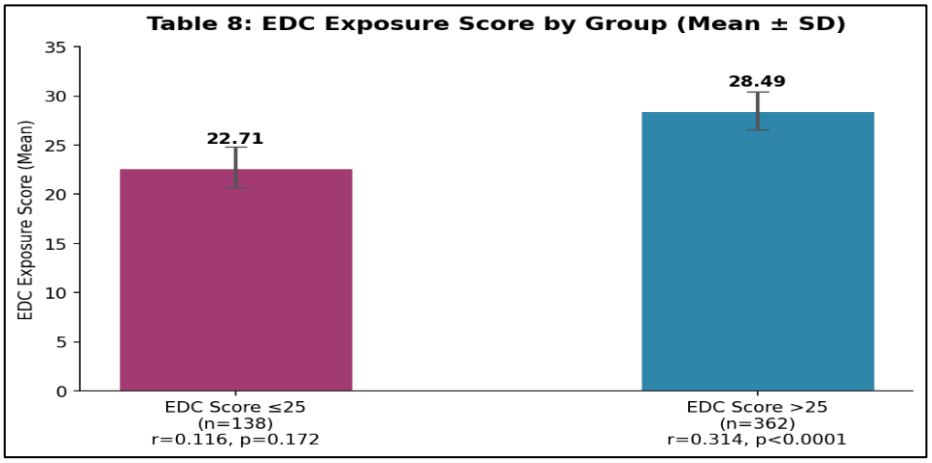


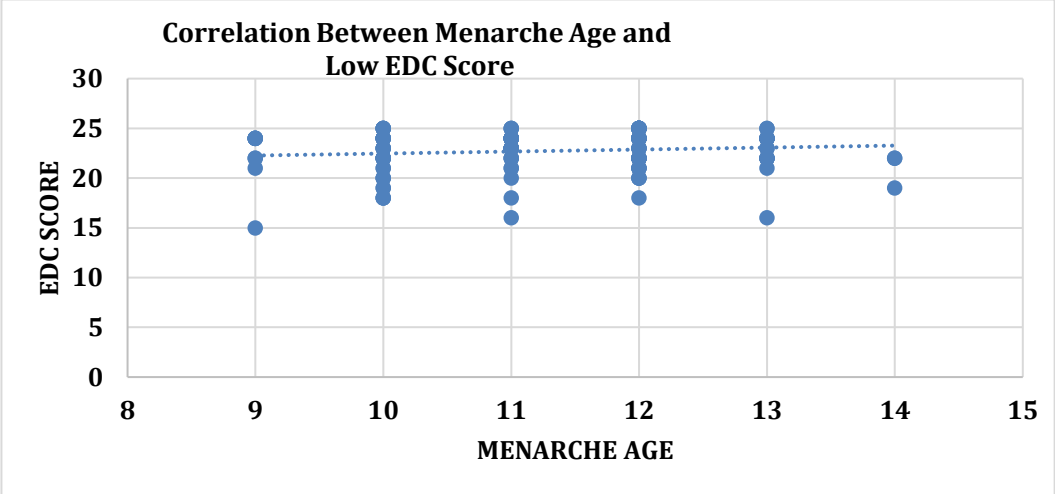
Correlation between EDC exposure score and age at puberty: Out of 500 participants, in the low exposure group (≤25), there were 138 participants, mean and standard deviation EDC score 22.715±2.084. In the high exposure group (>25), there were 362 participants, there was a strong and significant association with earlier puberty, Mean and standard deviation EDC score 28.488±1.932 This suggests that EDCs may not affect puberty at low levels, but higher exposure can lead to earlier onset.

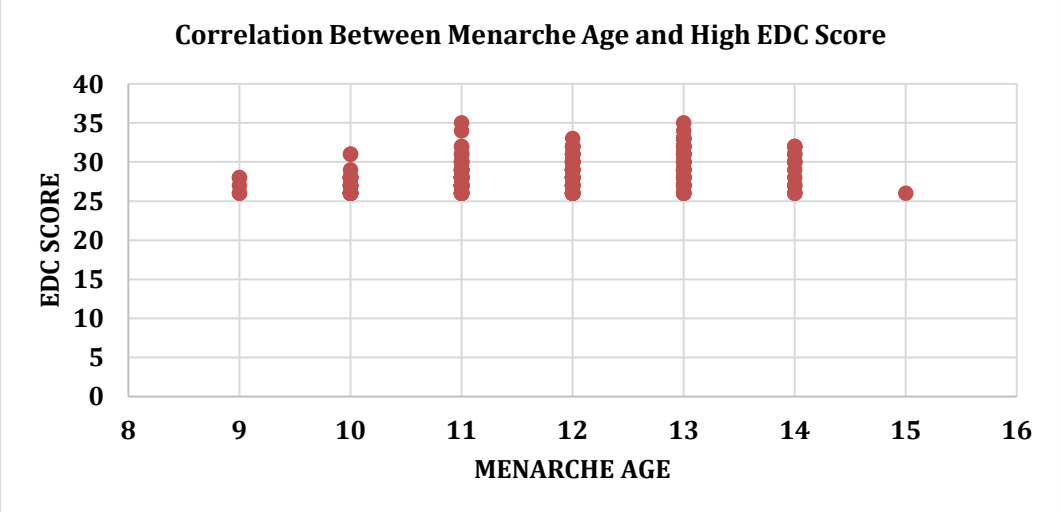
Table 8: Correlation between EDC exposure score and age at puberty

Variable	EDC Score	Mean ± SD	Correlation coefficient (r)	p-value
EDC exposure score	≤25 (n=138)	22.715±2.084	0.116	0.172
	>25 (n=362)	28.488±1.932	0.3143	<0.0001
Age at menarche	11.746±1.154			

Figure 8: Correlation between EDC exposure score and age at puberty





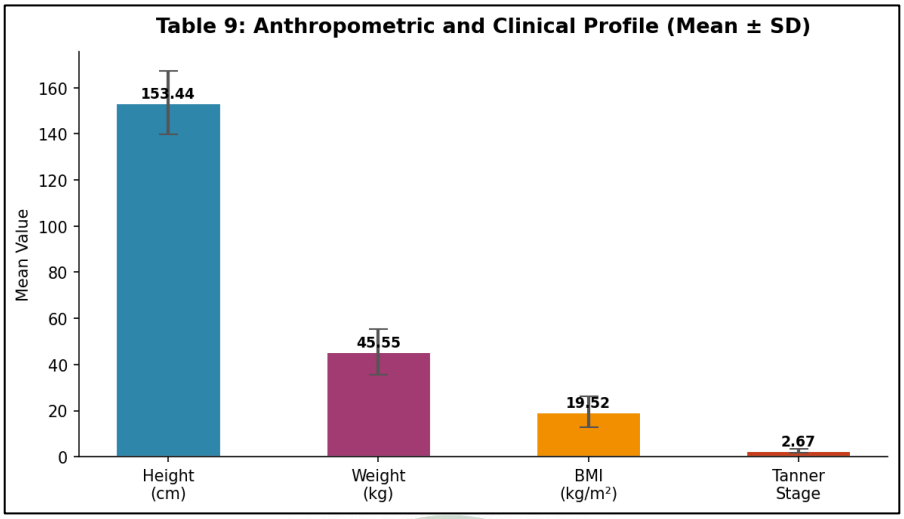


Anthropometric and clinical profile: Out of 500 participants, height mean value is 153.443±13.778, weight mean value is 45.548±9.895, BMI mean value is 19.521±6.754, Tanner stage mean value is 2.668±0.841, as shown in the table below.

Table 9: Anthropometric and clinical profile

Variable	Mean ± SD
Height (cm)	153.443±13.778
Weight (kg)	45.548±9.895
BMI (kg/m^2)	19.521±6.754
Tanner stage	2.668±0.841

Figure 9: Anthropometric and clinical profile



Questionnaire-Based Survey

Structured questionnaire to collect.

Demographic details

1) Name
2) Age (In Yrs)

Pubertal milestones

1. Menarche
2. Regularity of menstruation: Regular/irregular
3. Menstrual flow: Duration

Interval

Quantity of flow

4.What type of symptoms do you experience during your menstrual period?

5.Appearance of secondary sexual characters:

Breast changes

Hair changes – Pubic, axillary

Changes in voice

Lifestyle factors

Physical Activity

1. How often do you engage in physical activity or exercise?
 - Daily
 - Weekly
 - Monthly
 - Rarely

2. What type of physical activity or exercise do you usually do? (Select all that apply)
 - Walking
 - Running
 - Swimming
 - Cycling
 - Team sports
 - Other (please specify)

3. How long do you typically engage in physical activity per session?

Diet and Nutrition

1. What type of diet do you usually follow?
 - Vegetarian
 - Vegan
 - Non-vegetarian
 - Other (please specify)

2. How often do you consume the following foods? (Scale: 1-5, where 1 = rarely and 5 = daily)
 - Fruits
 - Vegetables
 - Whole grains
 - Processed meats
 - Sugary drinks
 - Processed snacks/ fast foods

3. Do you take any dietary supplements? (Select all that apply)
 - Vitamins
 - Minerals
 - Herbal supplements
 - Other (please specify)

Stress and Mental Health

1. How often do you feel stressed or anxious?
 - Daily

- Weekly
- Monthly
- Rarely

2. Have you ever been diagnosed with a mental health condition, such as depression or anxiety disorder?

Yes / No

Environmental Exposures:

1.Do you live in urban or rural areas?

2.How often do you spend time outdoors?

3.Do you live near any industrial sites, highways, factories or airports?

Exposure to EDC sources

Personal Care Products

1.What type of shampoo do you use?

2. what type of makeup and cosmetics products do you use?

Name:

Company name:

3.What type of soap or body wash do you use?

4.Do you use conditioner?

Food and Water:

1.In which type of container do you usually drink or store water?

2.How often do you eat canned foods?

3.Do you consume foods packaged in plastics or polythene covers?

4.Which utensils do you use for cooking?

5.Do you use water filter or purification system at home?

6.Do you store food in glass /plastic/steel containers?

Toys:

1 What type of toys do you play with most? (Select all that apply)

☐ Plastic toys
☐ Wooden toys
☐ Soft toys/stuffed animals
☐ Electronic toys
☐ Others (please specify): ___

Home Environment

1.What type of cleaning products do you use in your home?

2.How often do you use disinfectants in your home?

3.What type of furniture do you have in your home?

Others:

1. Have you ever been diagnosed with an endocrine disorder like thyroid disease?

- Yes
- No

2. Are you currently taking any medications or supplements that may affect your endocrine system?

- Yes
- No

B. Clinical and Biochemical Assessments

Anthropometric Measurements: Height:

Weight:

BMI:

Tanner staging for puberty assessment:

DISCUSSION

The present study was conducted to investigate the association between EDC exposure and early puberty using a survey-based approach and compare it with the concept of *Dushi visha*.

School-aged girl children and adolescents fitting the inclusion criteria were taken for the study. A structured questionnaire covering different aspects such as demographic details, pubertal milestones, physical activity, diet and nutrition, stress and metal health, environmental exposures to different EDCs and clinical assessment was used.

A majority of urban population was considered as it is associated with greater exposure to EDCs through industrial pollutants, plastic and its derivatives, canned foods, personal care products and so on.

The survey results show predominant of participants aged 14-15 years (59%) attained pubertal milestones followed by small proportion of 10–12-year-olds (3%) which reflects early pubertal onset as an emerging concern. Even though 3% is small proportion it roughly corresponds to 14 girls per 500 which is clinically relevant finding that is consistent with the global epidemiological estimate.

The mean menarche age is 11.75 years which is notably lower than the Indian national mean that is 14.3 years. This population level of early puberty suggests that involvement of different factors including EDC exposure. 25% of the participants showed early thelarche (breast development) while 23% showed prevalence of irregular menstruation. These statistical values indicate hormone disruption. 77% of the study population showed developed both pubic and axillary hair indicating relatively advanced pubertal progression consistent with the study objective.

Among the lifestyle factors considered 53% of the participants have high fast-food consumption which is concerning as the food packaging, plastic containers, and processed ingredients are sources of BPA, phthalates, and PFAS all being potent EDCs. From an Ayurvedic perspective, excess *Guru* (heavy), *Ushna* (hot), and *Vidahi* (pungent/processed) foods increase Pitta and predispose to *Ama* (toxin) formation, which parallels the *Dushi Visha* mechanism.

The study shows 30% of participants live near industrial zones which is a well-known risk factor for EDC exposure. These environments emit persistent organic pollutants (POPs), heavy metals, vehicle

exhaust particulates etc., which are capable of disrupting the hypothalamic-pituitary-gonadal (HPG) axis.

80% of study population show usage of plastic products while 76% use cosmetics which are concerning. Among the plastic exposure BPA, Phthalates and in cosmetics parabens, phthalates were the commonly found EDCs. BPA can bind to estrogen receptors and mimic estrogen action. Childhood exposure to phthalates was associated with altered pubertal development. Parabens act as a weak estrogen and advance pubertal changes.

The p-value of <0.001 shows that there is a significant association between EDC exposure and early puberty in girls. While absolute numbers appear modest, the proportional analysis is key: high EDC group 5/362=1.3% early puberty; low EDC group 9/138=6.8% puberty. This apparent paradox (higher rate in 'low' EDC group) may reflect the threshold and saturation effects of EDC accumulation, misclassification of exposure categories, or confounding variables not fully captured in this cross-sectional design.

The study findings reveal a dose-dependent relationship between EDC exposure and pubertal timing. In the low-EDC group (score<=25), r=0.116 with p=0.172 is non-significant - suggesting that below a threshold level, EDC exposure does not produce a measurable effect on pubertal timing. In the high-EDC group (score>25), r=0.314 with p<0.0001 demonstrates a significant positive correlation: as EDC exposure increases it is associated with advancing pubertal onset (earlier menarche). The predominance of participants in the high-exposure group (n=362, 72.4%) highlights a substantial population-level burden of EDC exposure. However, due to the cross-sectional nature of the study, causal inferences cannot be made.

The anthropometric results show Mean BMI of 19.52kg/m^2 which is within the normal range for adolescent girls. The relatively normal BMI points more specifically to chemical/environmental factors (EDCs) as the primary mediators of pubertal acceleration and obesity driven. Mean Tanner Stage of 2.67 indicates that the average participant was in mid-puberty at the time of survey, consistent with the 14-15 age majority and the mean menarche age of 11.75 years. Wide standard deviations in height (±13.78cm), weight (±9.90kg), and BMI (±6.75kg/m2) reflect genuine biological heterogeneity- important for generalisation and statistical modelling.

From Ayurvedic stand point of view exposure to various chemical/toxins over a period of time results in *Dushi visha* and manifestation of diseases of different tissue systems. In this regard exposure to EDCs through different pathways such as lifestyle factors, environmental exposures, dietary, cosmetics causing hormonal disruption and affective pubertal health can be well correlated to *Dushi visha* manifestation. This cross-sectional survey provides robust epidemiological evidence that EDC exposure-through multiple overlapping pathways is significantly associated with early pubertal onset in girls. The findings are consistent with the Ayurvedic concept of *Dushi Visha* as a model for understanding chronic, cumulative toxin-mediated hormonal disruption and its clinical manifestations in pediatric reproductive health.

Limitations of the study

1. The cross-sectional design limits the ability to establish a causal relationship between endocrine-disrupting chemical (EDC) exposure and early pubertal onset. The associations observed reflect correlations at a single point in time and do not confirm temporality.
2. Potential confounding factors such as genetic predisposition, nutritional status, socioeconomic factors, and environmental variability were not fully controlled.
3. The study sample was predominantly from urban settings, which may limit the generalizability of the findings to rural population.
4. The correlation observed between EDC exposure and pubertal timing does not necessarily imply a direct causal effect, and the possibility of residual confounding cannot be excluded. Longitudinal studies with objective exposure assessment are required to validate these findings.

CONCLUSION

The present study was conducted to evaluate the association between endocrine-disrupting chemicals (EDCs) and early puberty in school going girls and to correlate with the Ayurvedic concept of *Dushi Visha*.

The cross-sectional survey conducted with 500 school-aged girls showed the exposure to EDCs through sources such as plastics, cosmetics, processed foods, and environmental pollutants is common in the study population.

The findings revealed that 3% of the participants had early puberty, and the mean age at menarche was 11.75 years, which is lower than the reported national and global average. Lifestyle and environmental factors such as high fast-food consumption, frequent use of plastic products, cosmetic use were identified as important sources of EDC exposure. Statistical analysis showed a significant association between higher EDC exposure and earlier pubertal onset, suggesting that prolonged exposure to these chemicals may influence hormonal balance and pubertal development.

In conclusion, the study highlights the growing impact of environmental and lifestyle-related chemical exposures on pubertal health in girls. Increasing awareness, reducing exposure to EDC sources, and adopting healthier lifestyle practices may help in preventing early hormonal disturbances and promoting better reproductive health.

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Declarations

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