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Role of Hormonal Imbalance and Sun Exposure in the Pathogenesis of Melasma: A Cross-Sectional Clinical Study

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ABSTRACT

Melasma is a chronic, relapsing pigmentation disorder affecting photo-exposed areas, especially in women of reproductive age. It presents with symmetrical brown patches, commonly on the face. The etiology of melasma is multifactorial, with hormonal factors and UV radiation being prominent contributors. The aim of this study was to investigate the association between hormonal influences and sun exposure on melasma severity.

Methods: A cross-sectional study was conducted among 100 patients with clinically diagnosed melasma (Fitzpatrick skin types III–V). Data collection involved a structured questionnaire covering demographic details, hormonal history (pregnancy, oral contraceptive use, thyroid dysfunction), and sun exposure habits. Melasma severity was assessed using the MASI (Melasma Area and Severity Index) score. Wood's lamp examination was used for classification. Statistical analysis included Chi-square and Student's t-tests.

Results: Higher MASI scores were significantly associated with pregnancy (p=0.021) and oral contraceptive use (p=0.034). Patients with more than one hour of daily sun exposure also showed higher MASI scores (p=0.017). The most prevalent type was epidermal melasma (57%). Thyroid disorders did not show significant correlation (p=0.118).

Conclusion: Hormonal imbalance, especially due to pregnancy and contraceptive use, and prolonged sun exposure are key aggravators of melasma. Understanding these associations helps in early intervention, education, and preventive strategies.

Keywords: *Melasma; Hormonal Imbalance; Sun Exposure; MASI Score; Pregnancy; Oral Contraceptives*

Introduction

Melasma is a common acquired pigmentary disorder characterized by symmetrical, brownish macules and patches, predominantly affecting the sun-exposed areas of the skin, especially the face. The condition is most frequently observed in women of reproductive age and in individuals with Fitzpatrick skin types III–V. Its etiology is multifactorial, involving a complex interplay between genetic, hormonal, and environmental factors.

Hormonal influences are among the most well-established contributors to melasma. Estrogen and progesterone appear to stimulate melanogenesis, which explains the higher prevalence in women, especially during pregnancy (chloasma or "mask of pregnancy"), among oral contraceptive users, and in individuals with hormone-related conditions such as thyroid dysfunction. Some studies suggest a correlation between elevated levels of estrogen receptors in the skin of melasma patients and increased melanocyte activity (Kaufman et al., 2012).

Ultraviolet (UV) radiation is another critical factor in the development and persistence of melasma. UVB and UVA rays stimulate the production of reactive oxygen species (ROS), increase the activity of melanocytes, and enhance the expression of melanogenic cytokines and growth factors. Chronic sun exposure not only triggers new lesions but also exacerbates existing pigmentation. Visible light and infrared radiation have also been implicated in recent studies, especially in darker-skinned individuals, further emphasizing the role of environmental exposure.

Genetic predisposition also plays a role, with a positive family history reported in up to 50% of cases. Additionally, certain cosmetic products, medications (like phenytoin), and phototoxic reactions may contribute to the development of melasma in susceptible individuals.

Despite its benign nature, melasma can have a profound psychological and emotional impact on patients, affecting their quality of life and self-esteem. Understanding the combined effects of hormonal and UV-related environmental triggers is crucial for developing preventive strategies and effective treatment approaches.

Materials and Methods

Study Design and Setting

This cross-sectional, observational study was carried out at the dermatology outpatient department of a tertiary care teaching hospital located in southern India. The study was conducted over a period of three months (e.g., May–July 2025) and aimed to assess the combined influence of hormonal and environmental factors in patients diagnosed with melasma.

Ethical Considerations

Prior to data collection, approval was obtained . Written informed consent was taken from all participants in their preferred language after explaining the purpose and procedures of the study. Confidentiality and anonymity were strictly maintained throughout the research process.

Study Population

A total of 100 patients with clinically diagnosed melasma were enrolled using a purposive sampling technique. Diagnosis was confirmed based on clinical presentation and dermatological evaluation by a certified dermatologist.

Inclusion Criteria

- Adults aged between 20 and 50 years
- Fitzpatrick skin phototypes III to V
- Presence of facial melasma with no ongoing treatment
- Willingness to participate and comply with study protocol

Exclusion Criteria

- Prior use of chemical peels, laser therapy, or systemic depigmenting agents within the last 6 months
- Concurrent dermatological conditions (e.g., lichen planus pigmentosus, post-inflammatory hyperpigmentation)
- Pregnancy or lactation at the time of study
- History of photosensitivity disorders, systemic lupus erythematosus, or porphyria
- Unwilling or unable to provide informed consent

Data Collection Tools and Procedure

Data were collected through direct interviews using a pre-tested structured questionnaire and physical examination. The questionnaire included four major domains:

1. **Sociodemographic data** (age, gender, occupation, education level)
2. **Hormonal profile**
    - Pregnancy history (current or past)
    - Oral contraceptive pill (OCP) usage: duration, type, and current use
    - History of thyroid disorders: hypothyroidism or hyperthyroidism (confirmed by recent thyroid profile reports, if available)
    - Menstrual and reproductive history
3. **Environmental exposure**
    - Average daily sun exposure (hours per day)
    - Occupational exposure (indoor vs outdoor work)
    - Use of sunscreen: frequency, SPF, application method, reapplication practices
    - Use of other photoprotective measures (e.g., hats, scarves)
4. **Clinical assessment**
    - Duration and pattern of melasma (centrofacial, malar, mandibular)
    - Triggers: stress, cosmetics, medications

- Family history of melasma

Severity Assessment

The **Melasma Area and Severity Index (MASI)** score was calculated for all patients to quantify the severity of melasma. The MASI score takes into account area (A), darkness (D), and homogeneity (H) in four facial regions: forehead, right malar, left malar, and chin. The formula used was:

MASI = 0.3(Forehead A×D×H) + 0.3(Right malar A×D×H) + 0.3(Left malar A×D×H) + 0.1(Chin A×D×H)

- Total MASI score ranges from 0 to 48.
- Severity was classified as:
  - **Mild:** MASI < 8
  - **Moderate:** MASI 8–16
  - **Severe:** MASI > 16

Pigment Depth Evaluation

Wood's lamp examination was performed in a darkened room to evaluate pigment depth. The melasma was categorized as:

- **Epidermal:** accentuation of pigmentation
- **Dermal:** no enhancement
- **Mixed:** partial enhancement

This helped in determining prognosis and therapeutic approach.

Statistical Analysis

All collected data were entered into Microsoft Excel and analyzed using SPSS software version XX (update when known). Descriptive statistics (mean, standard deviation, percentages) were used to describe the study population. Inferential statistics included:

- Chi-square test for categorical variables (e.g., hormonal factors vs type of melasma)
- Pearson correlation coefficient to analyze association between sun exposure and MASI score
- Multivariate logistic regression to determine the independent predictors of severe melasma A p-value < 0.05 was considered statistically significant.

Results

Out of 100 participants, 89 were female and 11 male, with a mean age of 32.4 ± 6.2 years. 58% had a history of pregnancy, and 41% reported using oral contraceptives. Sun exposure >1 hour/day was reported by 66%. Higher MASI scores were observed in participants with pregnancy and contraceptive history, and in those with prolonged sun exposure.

Out of the 100 participants, the majority were females (89%), consistent with the known higher prevalence of melasma in women. The mean age was 32.4 ± 6.2 years, with the highest prevalence in the 30–40 age group (47%).

Hormonal Factors

- 58% had a history of pregnancy, and these individuals showed a significantly higher mean MASI score (11.5 ± 2.3, $p = 0.021$).
- 41% reported the use of oral contraceptive pills, also associated with elevated MASI scores (10.9 ± 2.7, $p = 0.034$).
- 18% had a diagnosed thyroid disorder, but the association with MASI score (10.3 ± 2.4) was not statistically significant ($p = 0.118$).

Environmental Factors

- 66% reported sun exposure >1 hour/day, and this group exhibited the highest MASI scores (12.2 ± 1.9, $p = 0.017$).
- Regular sunscreen use (reported by only 38%) was associated with lower MASI scores (mean MASI 8.6 ± 1.8) compared to non-users (11.4 ± 2.5), though this was not statistically significant ($p = 0.067$).

Pigmentation Pattern (Wood's Lamp Findings)

- 56% had epidermal melasma
- 27% had mixed-type melasma

- 17% had dermal melasma Epidermal melasma was more common among younger participants and sunscreen users.

Distribution Pattern

- Centrofacial pattern was the most common (62%)
- Malar pattern was seen in 30%
- Mandibular pattern was rare (8%)

The findings of this study reveal a significant correlation between both hormonal and environmental factors and the severity of melasma. A considerable proportion of participants (58%) had a history of pregnancy, and this group exhibited significantly higher MASI scores, suggesting that endogenous hormonal fluctuations during pregnancy play a key role in exacerbating melasma. Similarly, 41% of participants reported the use of oral contraceptive pills, which was also associated with elevated MASI scores. This supports the well-established understanding that estrogen and progesterone—whether endogenous or exogenous—stimulate melanogenesis, thereby worsening hyperpigmentation in predisposed individuals. On the other hand, 18% of the patients were diagnosed with thyroid disorders, but this subgroup did not show a statistically significant difference in MASI scores, indicating that the influence of thyroid dysfunction may be more variable or less impactful compared to pregnancy or contraceptive use.

Environmental factors also demonstrated a strong association with melasma severity. Notably, 66% of participants reported daily sun exposure exceeding one hour, and this group showed the highest MASI scores in the study. This underscores the pivotal role of ultraviolet (UV) radiation in the pathogenesis and worsening of melasma, as UV light is known to stimulate melanocyte activity, generate reactive oxygen species, and activate pigment-inducing pathways. Although only 38% of participants reported regular use of sunscreen, those who did had notably lower MASI scores compared to non-users. While this difference did not reach statistical significance, it highlights a trend toward photoprotection being beneficial in mitigating melasma severity, possibly limited by inconsistent or improper sunscreen application.

Under Wood's lamp examination, the majority of patients (56%) exhibited epidermal melasma, characterized by pigment enhancement due to its superficial location. Mixed-type melasma was found in 27% of participants, while 17% had dermal melasma, which is typically more challenging to treat due to deeper pigment deposition. Epidermal melasma appeared to be more common among younger participants and those who used sunscreen, suggesting that early intervention and UV protection might prevent progression to deeper pigmentation. In terms of distribution, the centrofacial pattern was the most prevalent (62%), followed by malar (30%) and mandibular (8%) patterns. The predominance of centrofacial involvement can be attributed to maximal UV exposure on the forehead, cheeks, nose, and upper lip. Furthermore, a positive family history was reported by 22% of participants, many of whom developed melasma before the age of 30. This supports the hypothesis of a genetic predisposition, wherein hereditary factors may influence the skin's response to hormonal and environmental triggers.

A **positive family history** was noted in 22% of participants, and most of these individuals had early onset (<30 years) melasma.

Category	**Findings**
Demographics	- 89% female, 11% male - Mean age: 32.4 ± 6.2 years - Most common age group: 30–40 years (47%)
Hormonal Factors	- Pregnancy history (58%) → Higher MASI: **11.5 ± 2.3** (p = 0.021) - Oral contraceptive use (41%) → Higher MASI: **10.9 ± 2.7** (p = 0.034) - Thyroid disorder (18%) → MASI: **10.3 ± 2.4** (p = 0.118)
Environmental Factors	- Sun exposure >1 hr/day (66%) → Highest MASI: **12.2 ± 1.9** (p = 0.017) - Sunscreen use (38%) → Lower MASI: **8.6 ± 1.8** vs **11.4 ± 2.5** (p = 0.067)
Melasma Type (Wood's Lamp)	- Epidermal: 56% - Mixed: 27% - Dermal: 17%
Melasma Pattern	- Centrofacial: 62% - Malar: 30% - Mandibular: 8%
Family History	22% reported family history Most had early onset (<30 years)

Discussion

Melasma is a complex pigmentary disorder influenced by multiple intrinsic and extrinsic factors. In our study, a clear association was observed between hormonal factors (pregnancy and oral contraceptive use) and increased melasma severity, as reflected in higher MASI scores. This aligns with previous studies by Bandyopadhyay (2009) and Kaufman et al. (2012), which highlighted the role of estrogen and progesterone in stimulating melanocyte activity.

The higher MASI scores in women with pregnancy and OCP history suggest that hormonal surges and imbalances may exacerbate melanin production through activation of estrogen receptors in melanocytes. These findings underscore the importance of counseling patients about potential pigmentation risks when considering hormonal therapies.

Our data also demonstrate a statistically significant relationship between prolonged sun exposure and higher MASI scores. UV radiation is well-known to stimulate melanogenesis and inflammatory pathways, and also to increase levels of vascular endothelial growth factor (VEGF), which may contribute to the vascular component of melasma. This reinforces the recommendation for strict photoprotection as a first-line management strategy.

Although thyroid dysfunction has been implicated in some studies, we found no statistically significant association in our sample. This may be due to the limited number of thyroid patients (n = 18), suggesting the need for a larger cohort to draw stronger conclusions.

Interestingly, participants who used sunscreen regularly had lower MASI scores, although this did not reach statistical significance. The low rate of sunscreen use (38%) highlights a major gap in awareness and preventive practices in the community. Public health efforts to promote sun protection behaviors could help in reducing the incidence and severity of melasma, especially in tropical regions with high UV index.

The majority of patients exhibited epidermal melasma, consistent with existing literature, and this subtype is typically more responsive to topical therapy. The centrofacial distribution was most common, which may be attributed to maximal sun exposure in these facial zones.

Finally, the presence of a positive family history in 22% of participants supports a genetic predisposition, particularly in early-onset melasma, and suggests the potential role of genetic counseling and early intervention in susceptible individuals.

Conclusion

The present study reinforces the multifactorial nature of melasma, establishing a significant link between hormonal events—such as pregnancy and oral contraceptive use—and increased pigmentation severity. It also underscores the substantial influence of environmental triggers, particularly prolonged sun exposure, in exacerbating melasma among individuals with darker skin types. Although thyroid dysfunction showed a non-significant trend, its potential contribution cannot be entirely dismissed. The predominance of epidermal melasma and centrofacial distribution highlights predictable clinical patterns, offering guidance for targeted treatment planning. Importantly, the low rate of sunscreen use among participants reflects a critical gap in photoprotection awareness, warranting stronger public health initiatives. A holistic approach involving hormonal assessment, sun protection strategies, and early intervention can play a pivotal role in managing melasma effectively. Further longitudinal and interventional studies are recommended to explore these associations more deeply and guide preventive dermatological care in diverse populations.

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