Study of Oxidative Stress and Antioxidant Markers in Premature Hair Greying

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Abstract:
Premature hair greying (PHG) is a dermatological condition characterized by the loss of hair pigment before the age of 25, with oxidative stress being implicated as a key factor in its pathogenesis. This study aimed to evaluate the levels of oxidative stress marker MDA and antioxidant marker SOD in individuals with PHG compared to a control group. A total of 202 subjects (101 with PHG and 101 controls) were included, and serum levels of MDA and SOD were measured using standardized laboratory techniques. Statistical analysis was performed using unpaired t-tests and logistic regression. The results showed that the mean MDA level was significantly higher in the PHG group (3.16 ± 0.71 mmol/L) compared to the control group (1.86 ± 0.66 mmol/L) ($p < 0.0001$), while the mean SOD level was significantly lower in the PHG group (77.58 ± 23.24 U/mL) compared to the control group (140.61 ± 31.19 U/mL) ($p < 0.0001$). Logistic regression analysis revealed a strong association between elevated MDA levels (OR = 18.89, 95% CI: 9.17 - 38.93) and reduced SOD levels (OR = 17.48, 95% CI: 8.69 - 35.16) with PHG. These findings demonstrate a significant imbalance in oxidative stress and antioxidant defense mechanisms in individuals with PHG, suggesting that oxidative stress plays a critical role in its pathogenesis. The study highlights the potential for antioxidant-based therapeutic interventions in the management of PHG.

Keywords: Premature hair greying, oxidative stress, malondialdehyde, superoxide dismutase, antioxidants.

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Introduction

The loss of hair pigment before the age of 25 is a common dermatological disorder known as premature hair greying (PHG), or canities. Particularly in younger people, it is a disorder that has major psychological and social ramifications in addition to its effects on appearance [1]. PHG is thought to be caused by a confluence of genetic, environmental, and metabolic variables, while its precise etiology is yet unknown [2]. Melanocytes, the cells that produce pigment in hair, are lost when follicles age too quickly, and oxidative stress has been identified as a major factor in these processes [3].

An imbalance between the body's antioxidant defense systems and the generation of reactive oxygen species (ROS) results in oxidative stress. ROS are extremely reactive substances that can harm lipids, proteins, and DNA in cells. Examples of these include superoxide anions, hydrogen peroxide, and hydroxyl radicals [4]. Oxidative stress is assumed to hasten the loss of melanocyte stem cells in the hair follicle bulge, which results in a decrease in melanin synthesis and the appearance of grey or white hair [5]. Lipid peroxidation produces malondialdehyde (MDA), a well-known indicator of oxidative stress that shows the degree of cellular damage brought on by ROS [6].

However, a vital antioxidant enzyme called superoxide dismutase (SOD) neutralizes ROS by turning them into hydrogen peroxide and oxygen, shielding cells from oxidative damage [7].

Numerous investigations have indicated that oxidative stress is a key factor in the pathophysiology of PHG. For example, people with PHG have been found to have higher amounts of ROS in their hair follicles and lower activity of antioxidant enzymes like SOD [8]. Additionally, environmental factors such as ultraviolet (UV) radiation, pollution, and smoking have been shown to exacerbate oxidative stress, further contributing to the premature aging of hair follicles [9]. Despite these findings, the relationship between oxidative stress markers (e.g., MDA and SOD) and PHG has not been thoroughly investigated, particularly in younger populations.

The purpose of this study is to assess the levels of the antioxidant marker SOD and the oxidative stress marker MDA in PHG patients and compare them to a control group. By doing this, we intend to gain a deeper comprehension of how oxidative stress contributes to the pathophysiology of PHG and offer suggestions for possible treatments that specifically target oxidative stress.

2. MATERIALS AND METHODS

A case control study was conducted involving 101 subjects with PHG and 101 controls. Participants were recruited from a dermatology clinic, and informed consent was obtained from all individuals. The study was approved by the Institutional Ethics Committee.

Inclusion Criteria: Subjects aged 18–25 years with clinically diagnosed PHG were included in the PHG group. Controls were healthy individuals with no history of premature greying.

Exclusion Criteria: Individuals with chronic illnesses, those taking medications affecting thyroid function or blood sugar levels, and smokers were excluded.

Sample Collection

Blood samples were collected from all participants, and serum levels of MDA and SOD were measured using standardized laboratory techniques. MDA levels were determined using TBARS method, while SOD activity was measured using ELISA method.

Statistical Analysis

Data analysis was done using descriptive statistics. Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as percentages. An unpaired t-test was used to compare mean MDA and SOD levels between the PHG and control groups. A p-value < 0.05 was considered statistically significant. Statistical analysis was performed using SPSS version 27.0.

Results

The study included 202 participants, divided into two groups: 101 individuals with premature hair greying (PHG) and 101 age- and gender-matched controls. The demographic characteristics of the participants are summarized in Table 1.

Table 1: Frequency distribution of age of subjects both groups

Age Interval (In Yrs.)	Control Group		PHG Group	
	n = 101	In %	n = 101	In %
18 - 19	28	27.72%	27	26.73%
20 - 21	30	29.70%	23	22.77%
22 - 23	29	28.71%	26	25.74%
24 - 25	14	13.86%	25	24.75%

PHG: Premature hair greying

The mean age of the PHG group was 21.47 ± 2.33 years, while the control group had a mean age of 21.01 ± 1.97 years. There was no significant difference in age or gender distribution between the two groups ($p > 0.05$), indicating that the groups were well-matched for these variables.

Oxidative Stress Marker (MDA):

The mean serum MDA level in the PHG group (3.16 ± 0.71 mmol/L) was significantly higher than in the control group (1.86 ± 0.66 mmol/L) ($p < 0.0001$). This finding indicates a marked increase in oxidative stress in individuals with PHG. The

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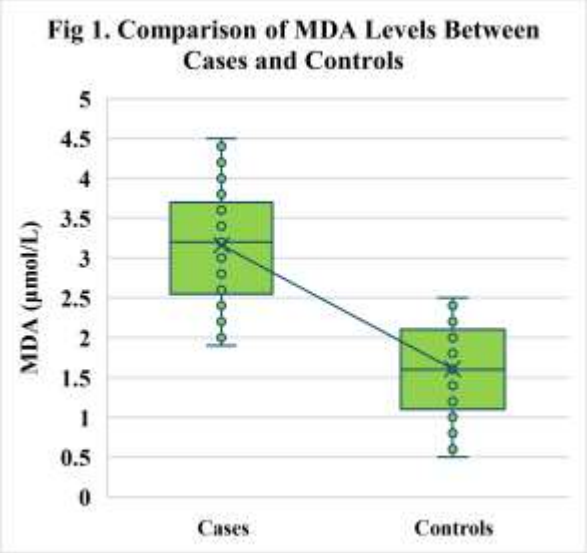
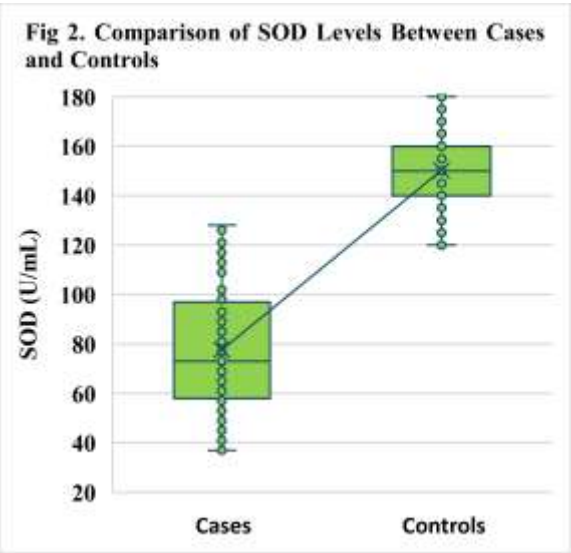
distribution of MDA levels across the two groups is presented in Table 3. In the PHG group, 75.25% of participants had MDA levels > 2.50 mmol/L, compared to only 13.86% in the control group. Conversely, 86.14% of controls had MDA levels within the normal range (0.50 - 2.50 mmol/L), while only 24.75% of the PHG group fell within this range. These results suggest that elevated MDA levels are strongly associated with PHG. The distribution of MDA levels across the two groups is presented in **Table2**.

Table 2: Frequency distribution of MDA of subjects both groups

MDA (In mmol/L)	Control Group		PHG Group	
	n = 101	In %	n = 101	In %
< 0.50	0	0%	0	0%
0.50 - 2.50	87	86.14%	25	24.75%
> 2.50	14	13.86%	76	75.25%

MDA: Malondialdehyde**;** **PHG:** Premature hair greying





Antioxidant Marker (SOD):

The mean serum SOD level in the PHG group (77.58 ± 23.24 U/mL) was significantly lower than in the control group (140.61 ± 31.19 U/mL) ($p < 0.0001$). This finding indicates a compromised antioxidant defense system in individuals with PHG. The distribution of SOD levels across the two groups is presented in Table 4. In the PHG group, 80.20% of participants had SOD levels < 100 U/mL, compared to only 18.81% in the control group. Conversely, 81.19% of controls had SOD levels within the normal range (100 - 200 U/mL), while only 19.80% of the PHG group fell within this range. These results suggest that reduced SOD levels are strongly associated with PHG. The distribution of SOD levels across the two groups is presented in **Table 3.**

Table 3: Frequency distribution of SOD of subjects both groups

SOD (In U/mL)	Control Group		PHG Group	
	n = 101	In %	n = 101	In %
< 100	19	18.81%	81	80.20%
100 - 200	82	81.19%	20	19.80%
> 200	0	0%	0	0%

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SOD: Superoxide dismutase**;** **PHG:** Premature hair greying

Association Between MDA, SOD, and PHG:
Logistic regression analysis was performed to assess the association between MDA, SOD, and PHG. Elevated MDA levels (> 2.50 mmol/L) were significantly associated with PHG, with an odds ratio (OR) of 18.89 (95% CI: 9.17 - 38.93, p < 0.0001). Similarly, reduced SOD levels (< 100 U/mL) were significantly associated with PHG, with an OR of 17.48 (95% CI: 8.69 - 35.16, p < 0.0001). These findings indicate that both elevated MDA and reduced SOD levels are strong predictors of PHG. The Association between serum levels of MDA and SOD in subjects with Premature canities is presented in Table 4.

Table 4: Association between serum levels of MDA and SOD in subjects with Premature canities by using logistic regression

Variables		Control	PHG	Odds Ratio	95% CI	Z-test	P - Value
MDA	**0.50 - 2.50**	87	25	-	-	-	-
	> 2.50	14	76	18.89	9.17 - 38.93	7.97	< 0.0001
SOD	**< 100**	19	81	17.48	8.69 - 35.16	8.02	< 0.0001
	100 - 200	82	20	-	-	-	-

MDA: Malondialdehyde**;** **SOD:** Superoxide dismutase**;** **PHG:** Premature hair greying

Descriptive Statistics:
Descriptive statistics for MDA and SOD in both groups are presented in Tables 8 and 9. The PHG group had a higher median MDA level (3.2 mmol/L, IQR: 2.6 - 3.7) compared to the control group (2.0 mmol/L, IQR: 1.3 - 2.3). Similarly, the PHG group had a lower median SOD level (73 U/mL, IQR: 58 - 96) compared to the control group (150 U/mL, IQR: 130 - 160). These findings further support the hypothesis that oxidative stress plays a central role in the pathogenesis of PHG. Descriptive statistics for MDA and SOD in both groups are presented in **Tables 5 and 6**.

Table 5: Descriptive statistics of Age, MDA, and SOD of control group

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
Age	18	24	21 (19-23)	21.01 ± 1.97
MDA	0.5	3.2	2 (1.3-2.3)	1.86 ± 0.66
SOD	59	180	150 (130-160)	140.61 ± 31.19

MDA: Malondialdehyde**;** **SOD:** Superoxide dismutase**;** **IQR:** Inter-quartile range;
SD: Standard deviation**;** **PHG:** Premature hair greying

Table 6: Descriptive statistics of Age, MDA, and SOD of PHG group

Variables	Minimum	Maximum	Median (IQR)	Mean ± SD
Age	18	25	22 (19-23)	21.47 ± 2.33
MDA	1.9	4.5	3.2 (2.6-3.7)	3.16 ± 0.71
SOD	37	128	73 (58-96)	77.58 ± 23.24

MDA: Malondialdehyde**;** **SOD:** Superoxide dismutase**;** **IQR:** Inter-quartile range;
SD: Standard deviation; **PHG:** Premature hair greying

Discussion
The findings of this study demonstrate a significant imbalance in oxidative stress and antioxidant defense mechanisms in individuals with PHG. The elevated levels of MDA in the PHG group indicate increased oxidative stress, while the reduced levels of SOD suggest a compromised antioxidant defense system. These results are consistent with previous studies that have implicated oxidative stress in the pathogenesis of PHG [10, 11].

The strong association between elevated MDA levels and PHG suggests that lipid peroxidation may play a critical role in the premature aging of hair follicles. MDA is a byproduct of lipid peroxidation, a process in which ROS attack polyunsaturated fatty acids in cell membranes, leading to the formation of reactive aldehydes such as MDA [12]. Elevated MDA levels have been observed in various conditions associated with oxidative stress, including aging, cardiovascular diseases, and neurodegenerative disorders [13]. In the context of PHG, the accumulation of MDA may contribute to the damage of melanocytes and the depletion of melanocyte stem cells, ultimately leading to the loss of hair pigment [14].

Similarly, the reduced SOD levels in the PHG group indicate that the inability to neutralize ROS may contribute to the loss of melanocytes and subsequent greying of hair. SOD is a key antioxidant enzyme that plays a crucial role in protecting cells from oxidative damage by converting superoxide radicals into less harmful molecules [15]. Reduced SOD activity has been observed in various conditions associated with oxidative stress, including aging, diabetes, and neurodegenerative diseases [16]. In the context of PHG, the reduced SOD levels may result in the accumulation of ROS, leading to oxidative damage to melanocytes and the premature aging of hair follicles [17].

The role of extrinsic factors such as environmental pollutants and UV radiation in exacerbating oxidative stress cannot be overlooked. UV radiation, in particular, has been shown to generate ROS in the skin and hair follicles, leading to oxidative damage and the depletion of melanocyte stem cells [18]. Similarly, environmental pollutants such as particulate matter and heavy metals have been shown to induce oxidative stress and contribute to the premature aging of hair follicles [19]. The interplay between intrinsic factors (e.g., genetic predisposition) and extrinsic factors (e.g., environmental exposures) in the development of PHG warrants further investigation.

The findings of this study have important implications for the management of PHG. The significant imbalance in oxidative stress and antioxidant defense mechanisms observed in individuals with PHG suggests that antioxidant-based therapies may be effective in preventing or delaying the onset of PHG. For instance, topical or systemic antioxidants such as vitamin E, vitamin C, and coenzyme Q10 have been shown to reduce oxidative stress and protect against oxidative damage in various conditions [20]. Additionally, lifestyle modifications such as reducing exposure to environmental pollutants and UV radiation may help mitigate oxidative stress and prevent the premature aging of hair follicles [21].

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