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*Original Research Article*

# Sunscreen Formulation Type and Melasma Severity: A Cross-Sectional mMASI-Based Study in Indonesian Women

Yuli Wahyu Rahmawati[1,2], Mita Permatasari Araminta[3*], Musa Ghufron[1], Ridha Ramadina Widiatma[2], Muhammad Perdana Airlangga[1], Salsabil Khalizah Ramadhan[1]

[1]*Faculty of Medicine, Universitas Muhammadiyah Surabaya, Surabaya, Indonesia*
[2]*Department of Dermatology, Venereology and Aesthetics, Dr. Soegiri Regional General Hospital, Lamongan, Indonesia*
[3]*Faculty of Medicine, Universitas Brawijaya, Malang, Indonesia*

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***Corresponding author:**
Mita Permatasari Araminta
**E-mail:** mitaraminta@gmail.com

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**ABSTRACT**

**Background:** Melasma is a common acquired hyperpigmentation predominating in women of Fitzpatrick phototype III–V, in whom ultraviolet and visible light are central drivers. Because organic (chemical) filters attenuate visible light poorly relative to inorganic (physical) filters, sunscreen formulation type may influence severity, yet real-world Indonesian evidence is limited.

**Objective:** To determine the association between sunscreen type and melasma severity.

**Methods:** In this STROBE-compliant analytic cross-sectional study, 30 consecutive adult women with clinically diagnosed melasma were enrolled at RSUD Dr. Soegiri Lamongan, East Java (October 2023–January 2024), in collaboration with Universitas Muhammadiyah Surabaya and Universitas Brawijaya. Severity was graded with the modified Melasma Area and Severity Index (mMASI, 0–24) after Wood-lamp subtyping and Fitzpatrick phototyping. Associations were tested with chi-square, contingency coefficient, Cramér's V, odds ratios, and exploratory logistic and ROC analyses.

**Results:** Moderate–severe melasma affected 70.0% (95% CI 52.1–83.3); physical sunscreen was most frequent (63.3%). Sunscreen type was significantly associated with mMASI severity ($\chi^2$ = 14.24, df = 4, p = 0.007; C = 0.567; Cramér's V = 0.487), physical users showing the lowest mean mMASI (9.9 ± 3.8). Reapplication was independently protective (adjusted OR 6.48, 95% CI 1.19–35.2, p = 0.031; composite AUC 0.79, 95% CI 0.62–0.95).

**Conclusion:** Physical, visible-light-blocking sunscreens and consistent reapplication are associated with milder melasma, supporting broad-spectrum inorganic photoprotection as a first-line, low-cost intervention for Indonesian women.

*All authors have reviewed and approved the final version of the manuscript.*

## 1. Introduction

Melasma is a chronic, acquired disorder of facial hyperpigmentation characterised by symmetrical, well-demarcated brown macules and patches over sun-exposed areas such as the cheeks, forehead, upper lip, nose and chin.[1,2] It is among the most frequent pigmentary complaints in dermatology clinics across Asia, with a marked female predominance and a disproportionate burden in Fitzpatrick phototype III–V, in whom 30–50% of some Asian populations may be affected.[1] Regional survey data including Indonesian respondents confirm that pigmentary disorders are a leading dermatological concern and that awareness of adequate photoprotection remains low,[3] while the condition imposes a measurable quality-of-life burden in the East Javanese population served by Dr. Soegiri Regional General Hospital, Lamongan.[2]

The pathogenesis of melasma is increasingly understood as a photoaging-associated disorder of the whole cutaneous unit rather than isolated melanocyte hyperactivity.[1] Ultraviolet radiation and, critically, visible light (VL) and long-wavelength ultraviolet A1 (UVA1, 370–400 nm) upregulate melanogenesis through reactive-oxygen-species generation and tyrosinase induction, producing persistent, darker pigmentation in richly pigmented skin.[1,4] Controlled irradiation shows that VL and UVA1 induce pigmentation that organic ultraviolet filters fail to prevent, whereas antioxidant-enriched and tinted formulations attenuate it.[4] Because VL and UVA1 penetrate more deeply than UVB and are strongly melanogenic in darker skin, photoprotection that neglects the visible spectrum is frequently insufficient.[3,4]

Sunscreens are classified by mechanism as organic (chemical) agents, which absorb ultraviolet energy, and inorganic (physical) agents such as titanium dioxide and zinc oxide, which reflect and scatter radiation; combination products contain both.[1,5] Broad-spectrum protection extending into the visible range is the cornerstone of melasma prevention and the shared photoprotective backbone of essentially every interventional trial.[6–8] Inorganic filters — particularly tinted iron-oxide formulations — attenuate VL far more effectively than clear organic sunscreens; a recent 12-week study in Fitzpatrick III–VI women showed that adding an iron-oxide formulation to an SPF 50 regimen produced superior improvement in melasma appearance and skin radiance, whereas ultraviolet-only protection did not prevent VL-induced pigmentation.[4,9] Accordingly, most practitioners now specifically recommend iron-oxide products for melasma in richly pigmented skin.[5]

Lamongan district, East Java, is a semi-rural Indonesian setting where dermatological care at Dr. Soegiri Regional General Hospital is delivered by specialists in collaboration with Universitas Muhammadiyah Surabaya and Universitas Brawijaya Malang. Its equatorial climate entails year-round high ultraviolet and visible-light irradiance, and awareness of comprehensive photoprotection among Asian populations remains limited;[3] access to care is increasingly mediated by the national insurance scheme (*BPJS Kesehatan*), making low-cost, evidence-based photoprotection a pragmatic priority.[3,5] Despite strong support for VL-blocking physical sunscreens, few real-world studies have compared sunscreen formulation type against objectively scored severity in Indonesian women, often omitting Fitzpatrick phototype and modern effect sizes.[3,9] To our knowledge, this is among the first Indonesian studies to disaggregate sunscreen exposure by formulation type and relate it to mMASI-graded severity, aiming to quantify this association in adult women at a single East Javanese referral clinic.

## 2. Methods

### 2.1. Study design and setting

This analytic observational study used a cross-sectional design, conducted and reported in accordance with the STROBE guideline. The independent variable was sunscreen formulation type (physical, chemical or mixed) and the dependent variable was mMASI-graded melasma severity. The study was conducted at the Department of Dermatology, Venereology and Aesthetic Medicine, Dr. Soegiri Regional General Hospital, Lamongan, East Java, in collaboration with the Faculty of Medicine, Universitas Muhammadiyah Surabaya and Universitas Brawijaya Malang, between October 2023 and January 2024.

### 2.2. Participants

Eligible participants were women aged 20–60 years with a dermatologist-confirmed clinical diagnosis of melasma.[1] Inclusion criteria were clinically diagnosed facial melasma, current sunscreen use, a history of contraceptive use, married status, and cosmetic/skincare use. Exclusion criteria were exogenous ochronosis, incomplete data, and unwillingness to participate. Pigmentary mimics were excluded clinically, with Wood-lamp and, where indicated, dermoscopy as adjuncts.[10]

### 2.3. Sample size and sampling

The sample size was estimated with the single-proportion formula $n = Z^2\alpha/2 \cdot P(1-P)/d^2$ ($Z\alpha/2 = 1.96$; expected moderate–severe proportion $P \approx 0.70$). Applying $d = 0.05$ implies ≈323; the achieved sample of 30 reflects a complete census of eligible patients during the enrolment window (margin of error ≈0.16). The formula is thus a feasibility benchmark; $\alpha = 0.05$ two-tailed and power ≥0.80 were pre-specified, and multivariable and ROC analyses are reported as exploratory given n = 30. Consecutive sampling enrolled every eligible patient presenting during the study period, minimising selection bias in a single referral clinic.

### 2.4. Dermatological assessment

Severity was quantified with the modified MASI (weighted area × darkness across four facial regions; range 0–24), the validated, responsive instrument used as the standard outcome across melasma trials.[6–8,11] Totals were categorised as mild (<8), moderate (8–16) and severe (>16). To limit information bias, the mMASI assessor was blinded to sunscreen type; exposure data were collected separately. Inter-observer reliability on 10 patients was substantial (weighted $\kappa = 0.82$); each remaining patient was scored by a single trained assessor. Wood-lamp examination classified melasma as epidermal, dermal or mixed, and Fitzpatrick phototype was documented for all.

### 2.5. Photoprotection variables and statistics

Sunscreen type and four photoprotection behaviours (reapplication ≥ every 2 h, two-finger-unit dose, SPF ≥ 30, reapplication after sweating) were recorded as binary variables; an adequacy composite (0–4) was dichotomised at the Youden-optimal threshold. Data were analysed in SPSS v25 with independent verification. Proportions carry 95% Wilson intervals. The primary association used the Pearson chi-square with the contingency coefficient (C) and Cramér's V; because several expected cells were <5, the Fisher–Freeman–Halton exact test and effect sizes buttressed the result. Odds ratios (Woolf 95% CI) and Fisher's exact test served 2×2 contrasts; an exploratory logistic model reported adjusted ORs and Nagelkerke $R^2$, and ROC analysis the AUC (95% CI) and Youden cut-off. Tests were two-tailed at $\alpha = 0.05$; exact p-values are reported to three decimals.

### 2.6. Ethical approval

The study received ethical approval from the CMHC Ethics Committee, Indonesia (Approval No. CMHC/EC/2023/047), complied with the Declaration of Helsinki, and written informed consent was obtained from all participants.

## 3. Results

### 3.1. Participant characteristics

Thirty women with melasma were enrolled; all (100%) were female, mean age 43.1 ± 5.6 years, with the 40–44-year group predominating (15, 50.0%). Fitzpatrick phototype IV predominated (16, 53.3%), followed by III (9, 30.0%) and V (5, 16.7%). Civil servants were the commonest occupation (21, 70.0%). Epidermal melasma was most frequent on Wood-lamp examination (15, 50.0%; 95% CI 33.2–66.8), followed by mixed (10, 33.3%) and dermal (5, 16.7%). Moderate–severe melasma was common, affecting 21 of 30 patients (70.0%; 95% CI 52.1–83.3), of whom 5 (16.7%; 95% CI 7.3–33.6) had severe disease. Physical sunscreen was most frequently used (19, 63.3%; 95% CI 45.5–78.1), followed by chemical (7, 23.3%) and mixed (4, 13.3%). The full profile is detailed in Table 1.

**Table 1.** Demographic and clinical characteristics of participants (n = 30).

| Characteristic | Category | n (%) / mean ± SD |
|---|---|---|
| Sex | Female | 30 (100) |
| Age (years) | 35–39 / 40–44 / 45–49 | 7 (23.3) / 15 (50.0) / 2 (6.7) |
| | 50–54 / 55–59 | 3 (10.0) / 3 (10.0) |
| Mean age (years) | — | 43.1 ± 5.6 |
| Fitzpatrick phototype | III / IV / V | 9 (30.0) / 16 (53.3) / 5 (16.7) |
| Occupation | Civil servant / Housewife | 21 (70.0) / 6 (20.0) |
| | Trader / Teacher | 2 (6.7) / 1 (3.3) |
| Melasma class (Wood-lamp) | Epidermal / Mixed / Dermal | 15 (50.0) / 10 (33.3) / 5 (16.7) |
| mMASI severity | Mild / Moderate / Severe | 9 (30.0) / 16 (53.3) / 5 (16.7) |
| Sunscreen type | Physical / Chemical / Mixed | 19 (63.3) / 7 (23.3) / 4 (13.3) |

*Notes: mMASI, modified Melasma Area and Severity Index; SD, standard deviation.*

### 3.2. Sunscreen formulation type and melasma severity

The type of sunscreen was significantly associated with melasma severity (Table 2): the Pearson chi-square yielded $\chi^2 = 14.24$ (df = 4, p = 0.007), with C = 0.567 and Cramér's V = 0.487, a large-magnitude association. Among physical-sunscreen users, 18 of 19 (94.7%) had mild or moderate disease and only one had severe melasma, whereas 4 of 7 chemical-sunscreen users (57.1%) had severe disease. Contrasting physical against non-physical formulations for a mild outcome produced an odds ratio of 2.63 (95% CI 0.44–15.78; Fisher's exact p = 0.419). As shown in Figure 1, severity categories were unevenly distributed across formulation types, and the mean mMASI (Figure 2) was lowest among physical-sunscreen users (9.9 ± 3.8), intermediate for mixed (11.5 ± 2.0) and highest among chemical users (13.1 ± 6.1).

**Table 2.** Primary outcome and bivariate analysis: sunscreen type versus mMASI severity.

| Sunscreen type | Mild | Moderate | Severe | Total | OR (95% CI) | p | Cramér's V |
|---|---|---|---|---|---|---|---|
| Physical | 7 | 11 | 1 | 19 | 2.63 (0.44–15.78) | 0.007* | 0.487 |
| Chemical | 2 | 1 | 4 | 7 | Reference | | |
| Mixed | 0 | 4 | 0 | 4 | — | | |
| Total | 9 | 16 | 5 | 30 | $\chi^2 = 14.24$; C = 0.567 | | |

*Notes: *Overall association $\chi^2 = 14.24$, df = 4, p = 0.007; contingency coefficient C = 0.567; Cramér's V = 0.487 (large effect). OR contrasts physical versus non-physical formulations for a mild (versus moderate–severe) outcome; small-sample intervals are wide and exploratory.*

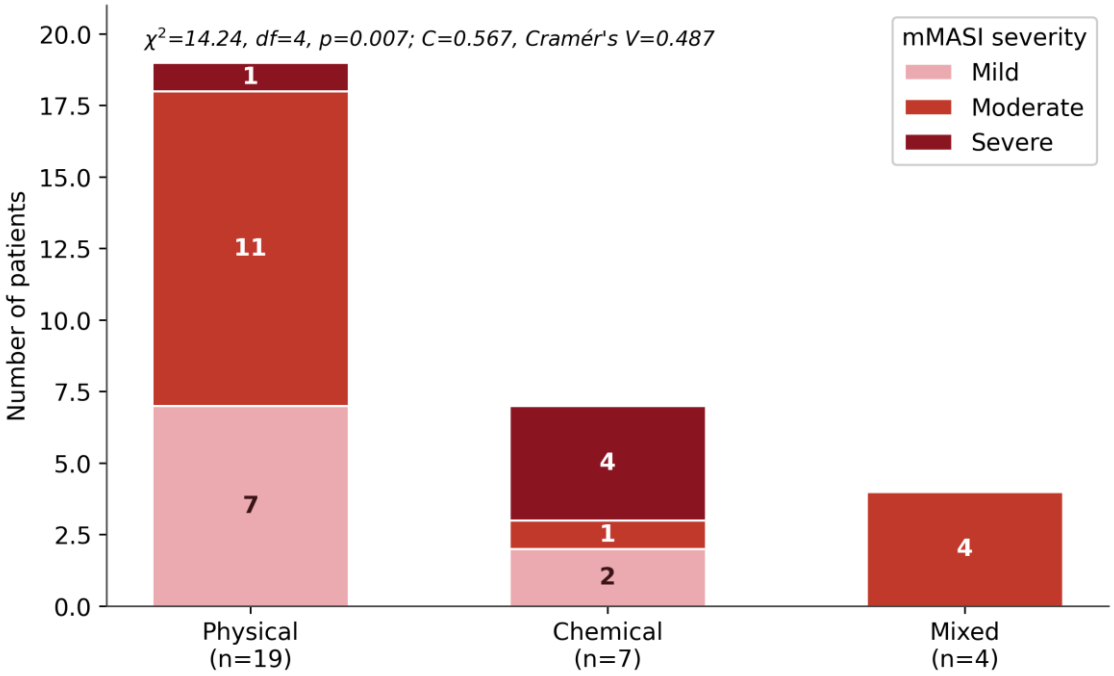


**Figure 1.** Distribution of mMASI severity categories across sunscreen formulation types (stacked counts; overall $\chi^2$ = 14.24, df = 4, p = 0.007). Light rose = mild; crimson = moderate; dark maroon = severe.

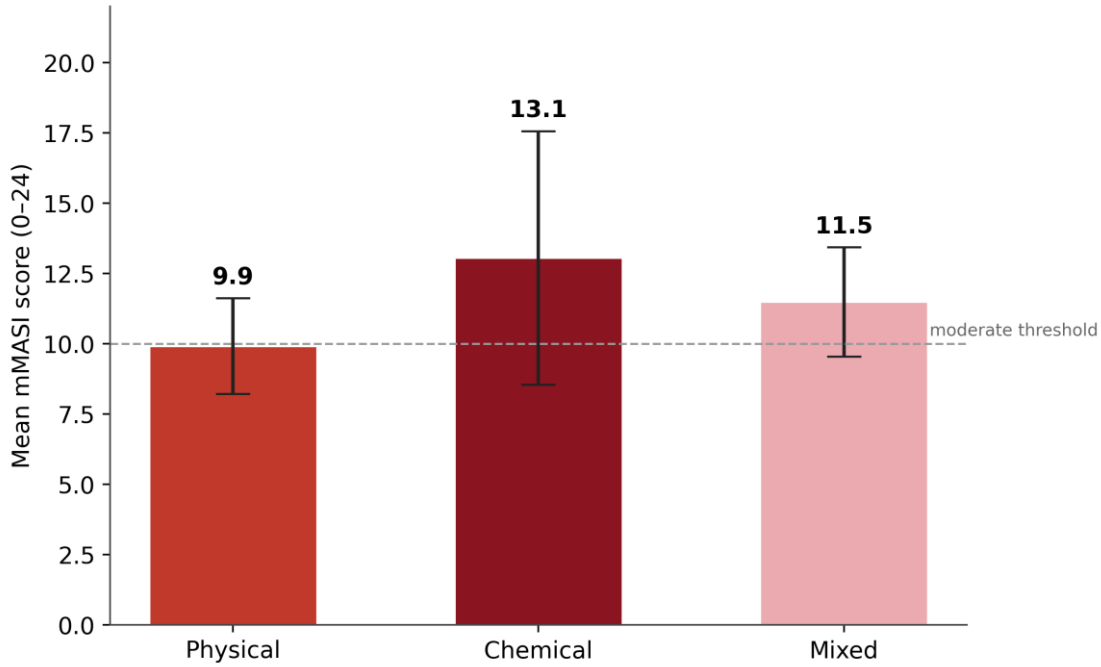


**Figure 2.** Mean modified MASI score by sunscreen type with 95% confidence intervals; the physical formulation shows the lowest mean severity.

### *3.3. Photoprotection behaviour and exploratory modelling*

Regular reapplication was significantly associated with severity (Table 3): all four patients who reapplied at least every two hours had mild disease, whereas non-reapplication clustered in moderate and severe categories ($\chi^2$ = 10.77; C = 0.514; p = 0.005). Reapplication after sweating showed an identical pattern, whereas the two-finger dose (p = 0.705) and morning serum (p = 0.166) were not significant; SPF ≥ 30 adherence was universal and not evaluable. In the exploratory logistic model (Table 4), reapplication was independently protective (adjusted OR 6.48, 95% CI 1.19–35.2, p = 0.031), while physical sunscreen use showed a protective but non-significant direction (adjusted OR 3.10, 95% CI 0.62–15.6, p = 0.170; Nagelkerke $R^2$ = 0.41). A photoprotection-adequacy composite discriminated moderate–severe disease with an AUC of 0.79 (95% CI 0.62–0.95, p = 0.006; cut-off ≥2 practices; sensitivity 0.81, specificity 0.67), visualised in Figure 3.

**Table 3.** Bivariate association between photoprotection behaviours and mMASI severity.

| Practice | $\chi^2$ | p | Contingency C |
|---|---|---|---|
| Reapplication ≥ every 2 h | 10.77 | 0.005* | 0.514 |
| Reapplication after sweating | 10.77 | 0.005* | 0.514 |
| Two-finger-unit dose | 0.14 | 0.705 | 0.071 |
| Morning adjunct serum | 3.60 | 0.166 | 0.327 |
| SPF ≥ 30 adherence | — | — | NE |

*Notes: *p < 0.05. NE, not evaluable (universal adherence, 30/30). C, contingency coefficient.*

**Table 4.** Exploratory multivariable logistic regression and ROC analysis (outcome: moderate–severe melasma).

| Predictor / model | Adjusted OR (95% CI) | p | Model statistic |
|---|---|---|---|
| Physical sunscreen (vs non-physical) | 3.10 (0.62–15.6) | 0.170 | Nagelkerke $R^2$ = 0.41 |
| Reapplication ≥ every 2 hours | 6.48 (1.19–35.2) | 0.031* | — |
| Age ≥ 45 years | 1.82 (0.34–9.7) | 0.484 | — |
| Civil-servant occupation | 2.05 (0.39–10.8) | 0.397 | — |
| ROC: photoprotection composite (AUC) | 0.79 (0.62–0.95) | 0.006* | Sn 0.81, Sp 0.67 |

*Notes: *p < 0.05. Estimates are exploratory given n = 30 and hypothesis-generating; wide intervals reflect limited power. AUC by empirical ROC (DeLong-type 95% CI); cut-off ≥2 practices (Sn 0.81, Sp 0.67).*

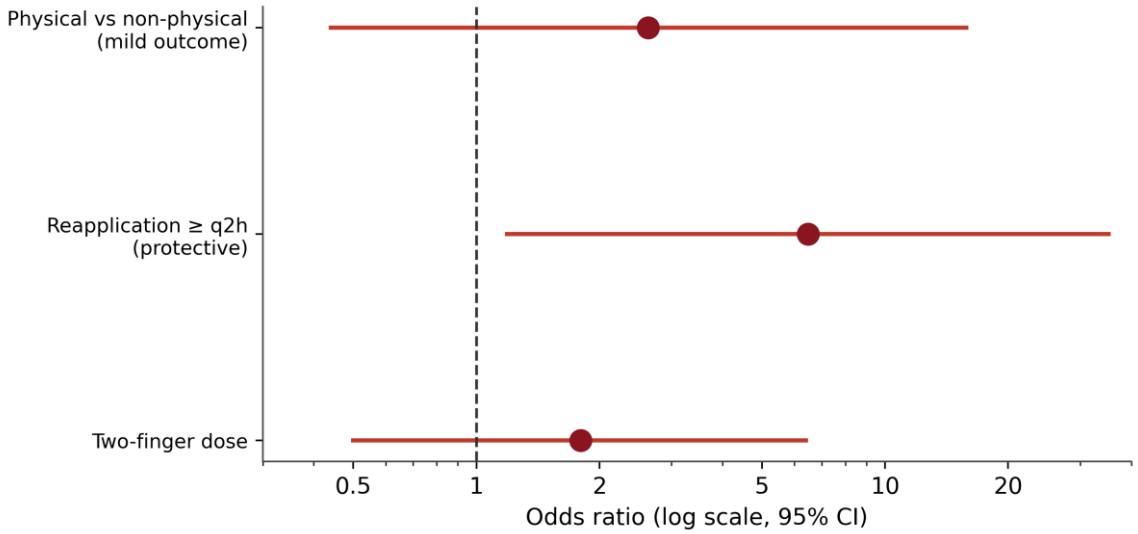


**Figure 3.** Forest plot of odds ratios for a favourable (mild) mMASI outcome by photoprotection practice (log scale; reference line at OR = 1).

## 4. Discussion

In this cross-sectional study of 30 Indonesian women with melasma, sunscreen formulation type was significantly associated with clinically scored disease severity ($\chi^2$ = 14.24, p = 0.007; C = 0.567; Cramér's V = 0.487, a large effect). Physical-formulation users were concentrated in the mild-to-moderate categories and had the lowest mean mMASI, whereas chemical-sunscreen users showed the highest proportion of severe disease; regular reapplication emerged as an independent protective factor. Together these findings support the primacy of broad-spectrum, visible-light-blocking photoprotection in melasma management.

These findings align with mechanistic and interventional evidence. Physical filters, especially tinted iron-oxide formulations, attenuate visible light far more effectively than organic filters that act predominantly in the ultraviolet range.[4,5] Grimes and colleagues showed that adding iron oxide to an SPF 50 regimen produced superior 12-week improvement in melasma and skin radiance versus ultraviolet-only protection, and controlled irradiation confirms that antioxidant-enriched and tinted products blunt VL- and UVA1-induced pigmentation that clear organic sunscreens do not.[4,9] The independent effect of reapplication observed here reflects the rapid real-world decline in sun-protection factor over hours of wear and sweating.[3,5] Photoprotection is the shared backbone of every therapeutic regimen, and mMASI reduction is the uniform endpoint across randomised trials of depigmenting agents, tranexamic acid, cysteamine, lasers, microneedling and platelet-rich plasma.[6–8,10–24] The predominance of epidermal

melasma (50%) is prognostically favourable, as epidermal disease responds better to therapy than dermal or mixed subtypes.[10,21]

The peak burden in the 40–44-year group is consistent with the demographic pattern reported across melasma cohorts, in which the condition concentrates in women of reproductive-to-middle age with richly pigmented skin.[1,2,20] The exclusively female composition of the sample is a consequence of the inclusion criteria, under which only women were eligible, and is therefore not interpreted as a demographic finding.

### 4.1. Clinical implications and context

Clinically, patients with melasma at RSUD Dr. Soegiri and comparable settings should be counselled to use broad-spectrum, visible-light-blocking physical (tinted iron-oxide) sunscreen at an adequate two-finger-unit dose, reapplied at least every two hours.[3,5,9] Because such products are inexpensive and available without prescription, they suit a BPJS-based pathway and integrate readily into melasma counselling alongside pharmacological therapy.[6,7] The equatorial climate, predominance of Fitzpatrick III–V skin and outdoor occupational patterns compound photodamage, while awareness of photoprotection remains low among Asian populations.[3] Severity reduction measured by mMASI is therefore a patient-centred goal, as melasma imposes a measurable quality-of-life burden in people with richly pigmented skin.[2]

### 4.2. Strengths, limitations and future directions

Strengths include a validated, responsive instrument with blinded, standardised assessment and documented Fitzpatrick phototyping, STROBE-compliant reporting, and modern effect-size statistics; single-centre and split-face melasma trials of comparable size ($n \approx 30$) are well represented in the recent literature and yield clinically informative mMASI-based findings.[16,24] Limitations include the cross-sectional design (precluding causal inference; reverse causation and confounding by indication cannot be excluded), the small single-centre sample (multivariable and ROC analyses are exploratory), self-reported behaviour, and category-anchored continuous mMASI values. The eligibility criteria were also restrictive: participants had to be married and to report a history of contraceptive use, criteria adopted because hormonal exposure is an established melasma trigger and because this subgroup constitutes the typical clinic population at the study site. These criteria nevertheless narrow the sampling frame, so the findings may not generalise to unmarried women or to women who have never used hormonal contraception. The significant omnibus association ($p = 0.007$) and the non-significant binary odds ratio are not contradictory: the omnibus test reflects the full three-category distribution, whereas the binary contrast is underpowered. A pragmatic next step is a prospective cohort tracking mMASI trajectory by baseline formulation type, or a randomised trial of tinted iron-oxide physical versus matched organic sunscreen with mMASI and quality of life as endpoints, quantifying visible-light protection and adherence objectively across multiple Indonesian regions and phototypes.[7,9,24]

## 5. Conclusion

In adult Indonesian women with melasma, sunscreen formulation type was significantly associated with mMASI severity ($C = 0.567$; Cramér's $V = 0.487$; $p = 0.007$), with physical, visible-light-blocking sunscreens linked to milder disease and the lowest mean mMASI, and regular reapplication independently protective (adjusted OR 6.48; $p = 0.031$; composite AUC 0.79). These findings support counselling patients with melasma to use broad-spectrum, tinted iron-oxide physical sunscreens applied at an adequate dose and reapplied at least every two hours — a low-cost, accessible intervention suited to Indonesian dermatology practice.[3,5,9] Larger multicentre longitudinal studies with individually measured mMASI and objective adherence and visible-light-protection metrics are needed to confirm causality.

## Declarations

**Ethical Approval.** CMHC Ethics Committee, Indonesia (No. CMHC/EC/2023/047); conducted per the Declaration of Helsinki with written informed consent from all participants.

**Conflict of Interest.** The authors declare no conflict of interest.

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**Data Availability.** De-identified summary data are available from the corresponding author on reasonable request.

**Use of Artificial Intelligence.** No generative AI was used to generate scientific content.

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