

Original Research Article

Body Mass Index Categories and Clinical-Epidemiological Profiles of Keloid Scars: A Retrospective Case-Control Study in a Tertiary Referral Hospital in Surakarta, Indonesia

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ARTICLE INFO

Article history:

Received: August 20, 2026

Revised: September 16, 2026

Accepted: October 12, 2026

Available Online: October 18, 2026

Published: October 21, 2026

Keywords:

Body mass index

Case-control studies

Keloid

Obesity

Pathological scarring

Wound healing

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E-mail: w13ka@yahoo.comDOI: [10.59345/sjdv.v4i2.370](https://doi.org/10.59345/sjdv.v4i2.370)

ABSTRACT

Background: Keloids are refractory fibroproliferative scars that grow beyond the original wound margin. Low-grade systemic inflammation linked to higher body mass index (BMI) has been proposed to promote keloid formation, but the clinical evidence is inconsistent.

Objective: To assess whether Asia-Pacific BMI categories are associated with keloid occurrence and to describe the clinical and epidemiological profile of keloid patients at an Indonesian tertiary referral hospital.

Methods: This retrospective case-control study at Dr. Moewardi General Hospital, Surakarta, Indonesia (January 2022 to December 2025) included 100 subjects: 78 keloid patients (ICD-10 L91.0) and 22 dermatology controls. BMI categories were underweight (<18.5 kg/m²), normal weight (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obese (≥25.0 kg/m²). Chi-square tests (Fisher's exact test where expected counts were small) and multivariable logistic regression were used.

Results: Among 78 keloid patients, 30 (38.5%) were normal weight, 22 (28.2%) obese, 13 (16.7%) underweight, and 13 (16.7%) overweight. BMI category was not significantly associated with keloid occurrence ($\chi^2 = 0.666$, $p = 0.881$; obese adjusted OR = 1.412, 95% CI: 0.418–4.770, $p = 0.578$). Sex ($p = 0.244$) and age category ($p = 0.305$) did not differ significantly. The anterior trunk was the most common site (47.4%). Wounds (29.5%) and surgical scars (28.2%) were the main triggers; intralesional triamcinolone acetonide was the main treatment (87.2%).

Conclusion: BMI category was not significantly associated with keloid occurrence, but the small control group ($n = 22$) limits power. Keloids were most often found at the anterior trunk and after skin injury.

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

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1. Introduction

Skin repair in adults follows four overlapping phases: vascular hemostasis, inflammation, cell proliferation, and extracellular matrix (ECM) remodeling.^{1–3} Negative feedback normally governs the shift from proliferation to matrix maturation, because it restrains fibroblast replication, triggers myofibroblast apoptosis, and restores the tensile structure of the dermis.⁴ When these checkpoints fail, healing turns into abnormal fibroproliferation. A pathological dermal scar forms. The two main types are hypertrophic scars and keloids.^{2,3} A hypertrophic scar stays within the boundary of the original injury and often regresses in

part over time. Keloids behave differently: fibroblasts keep proliferating and depositing collagen, and the lesion invades adjacent, uninjured reticular dermis without regressing on its own.^{2,3} Clinically, a keloid is a raised, firm, erythematous or hyperpigmented nodule or plaque. Patients report chronic discomfort, throbbing pain, itch, hyperesthesia, restricted joint motion, disfigurement, and psychological distress, and health-related quality of life falls accordingly.^{2,5}

Keloid management is still a difficult problem for dermatologists and reconstructive surgeons.^{6,7} Recurrence after monotherapy is common. It ranges from 50% to 90% after simple excision and from 30% to 50% after intralesional corticosteroid alone, and even

multimodal protocols that combine surgery, intralesional antimetabolites, and adjuvant superficial radiotherapy report recurrence of 20% to 40%.⁶⁻⁹ Decades of research have not fully explained how keloids start, invade locally, and resist treatment.^{3,10,11} The disease is probably multifactorial. Genetic susceptibility, local biomechanical strain, microvascular changes, chronic deep dermal inflammation, and possible systemic metabolic influences all seem to play a part.¹⁰⁻¹²

At the cellular level, keloids contain a subpopulation of activated dermal fibroblasts that resist senescence. These cells respond excessively to growth factors and show defective apoptotic signaling.^{4,13} Dysregulated transforming growth factor-beta (TGF- β) signaling is central to the fibrotic cascade.^{4,13-15} In healthy wounds, TGF- β 1 is expressed briefly to recruit fibroblasts and drive matrix deposition, and it is then downregulated. In keloid tissue, dermal fibroblasts overexpress the TGF- β 1 and TGF- β 2 ligands constitutively, express less of the antifibrotic TGF- β 3 isoform, and carry more type I and II TGF- β receptors on their surface.¹³ This signaling pattern sustains transcription of the collagen type I (COL1A1, COL1A2) and collagen type III (COL3A1) genes through canonical Smad2/3 phosphorylation and downstream non-canonical mitogen-activated protein kinase (MAPK) pathways.^{4,15} The keloid fibroblast secretome is also altered. It contains more vascular endothelial growth factor (VEGF), platelet-derived growth factor (PDGF), connective tissue growth factor (CTGF/CCN2), and interleukin-6 (IL-6), and the balance between tissue inhibitors of metalloproteinases (TIMP-1, TIMP-2) and matrix metalloproteinases (MMP-1, MMP-3, MMP-9) is disturbed.^{4,16-18} The result is steady accumulation of thick, disorganized, hyalinized collagen bundles that replace the normal dermal architecture.¹⁸

The epidemiology of keloids shows clear demographic, racial, and anatomical differences, which suggests that the cause is complex.^{5,19-21} Keloids are most frequent in people with darker pigmentation. The highest prevalence has been documented in people of African descent (4.5% to 16.0%), followed by Hispanic, South Asian, and East Asian groups. In Northern European Caucasians the condition is rare (<0.1%).^{5,19,20} Keloids can appear at any age, from early childhood to old age, but onset peaks in adolescence and young adulthood (ages 10 to 30 years).^{5,22} This peak has traditionally been explained by skin elasticity, rapid cell turnover, active collagen synthesis, higher levels of circulating sex steroids and growth hormone, and more frequent trauma, piercing, and inflammatory acne vulgaris at these ages.^{3,5} In Indonesia and elsewhere in Southeast Asia, tertiary dermatology clinics see keloid patients across a broad age range. This reflects heavy local use of care for symptomatic and disfiguring scars.^{21,22}

Where keloids occur on the body gives another clue to their pathogenesis. They are not spread at random. The anterior chest (pre-sternal region), upper back, shoulders, deltoid areas, and ear lobules are favored sites, and the palms, soles, and scalp are spared.²³⁻²⁵

Biomechanical research ties these sites to the highest continuous, multidirectional resting tension and repeated cyclic stretch.²³⁻²⁵ Every breath pulls the anterior chest outward and laterally, thousands of times a day.^{23,24} At the cellular level, mechanotransduction depends on membrane-bound mechanosensitive ion channels, mainly Piezo1 and transient receptor potential (TRP) channels, and on integrin-mediated focal adhesions.^{11,26} Sustained strain opens Piezo1 channels. Calcium (Ca^{2+}) enters the cell rapidly and activates focal adhesion kinase (FAK), Rho-associated protein kinase (ROCK), and extracellular signal-regulated kinase (ERK1/2).²⁶ The co-activators YAP (Yes-associated protein) and TAZ (transcriptional co-activator with PDZ-binding motif) then move into the nucleus, bind TEAD transcription factors, and upregulate Engrailed-1 (En1) and profibrotic gene networks. Fibroblasts end up in a self-perpetuating fibrotic state.²⁷

Mechanobiology is only one line of work. Interest has also grown in whether systemic metabolic dysregulation and adiposity contribute to fibroproliferative disease.^{28,29} Body mass index (BMI), body weight in kilograms divided by height in meters squared (kg/m^2), is the standard epidemiological proxy for adult nutritional status and for classifying obesity.^{30,31} Adipose tissue is more than a fat store. It is an active endocrine and immune organ that releases bioactive peptides called adipokines and classic pro-inflammatory cytokines.^{29,32} In obesity, adipocytes enlarge progressively. Local hypoxia, cellular senescence, and loss of microvessels follow in the expanding fat pads.²⁹ The hypoxic stress draws in pro-inflammatory CD4⁺ Th1 lymphocytes and M1-polarized macrophages in large numbers. They form crown-like structures around dying adipocytes and keep systemic inflammation at a chronic, low-grade level.^{29,32}

Obese individuals typically show raised circulating leptin, resistin, tumor necrosis factor-alpha (TNF- α), interleukin-6 (IL-6), and monocyte chemoattractant protein-1 (MCP-1), together with reduced adiponectin.³²⁻³⁴ Leptin acts directly on human fibroblasts, in a concentration-dependent way, to promote fibrosis. It enhances proliferation and migration and augments TGF- β -dependent collagen transcription in dermal, hepatic, and pulmonary matrices.^{35,36} Adiponectin does the opposite. It is a systemic counter-regulator with anti-inflammatory, insulin-sensitizing, and antifibrotic properties.^{33,37} Signaling through the AdipoR1 and AdipoR2 receptors stimulates adenosine monophosphate-activated protein kinase (AMPK) and peroxisome proliferator-activated receptor-gamma (PPAR- γ), suppresses nuclear translocation of nuclear factor-kappa B (NF- κ B), reduces Smad2/3 phosphorylation, and promotes myofibroblast dedifferentiation.³⁷ On this basis, some researchers have proposed that chronic metabolic inflammation and altered adipokine levels at a higher BMI act as a permissive cofactor. Dermal fibroproliferation would be amplified, and the risk of keloid formation after skin injury would rise.^{33,35,37}

The theory is attractive. The clinical evidence, however, is limited and mixed.^{22,38,39} In a US electronic health record cohort, obesity was more common among keloid patients than among people without keloids.²² In a Chinese retrospective controlled study, a BMI of 25 kg/m² or higher had an odds ratio of 1.546 for keloid ($p = 0.077$), and systolic hypertension was also related to keloid.³⁹ Rutherford and Glass (2017) examined the association of keloids with hypertension and obesity in a case-control study.⁴⁰ Abdu Allah et al. (2019) measured BMI in 60 Egyptian keloid patients and 30 matched healthy controls while studying interleukin-6,⁴¹ and Shi (2026) asked in a letter whether obesity is truly a risk factor for keloid development.³⁸

Most scar studies have used the standard World Health Organization (WHO) BMI classes, which were developed mainly in Caucasian populations. This is a further limitation. In those classes, overweight is a BMI of 25.0–29.9 kg/m² and obesity is a BMI ≥ 30.0 kg/m².^{42,43} Asian populations differ in body composition. They carry more body fat and more metabolically harmful visceral fat, and cardiovascular and metabolic risk appears at lower BMI than in Western populations.^{42,43} The WHO Western Pacific Region and the International Association for the Study of Obesity therefore set modified Asia-Pacific BMI cut-offs: underweight (<18.5 kg/m²), normal weight (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obese (≥ 25.0 kg/m²).^{30,42} Southeast Asian cohorts need these regional criteria for accurate assessment of nutritional status and metabolic risk. Yet Indonesian studies of Asia-Pacific BMI categories and keloid occurrence are almost absent.^{30,42}

The study is an observational case-control study at a tertiary academic referral center in Central Java, Indonesia, and it applies standardized Asia-Pacific BMI thresholds to test the hypothesis that a higher BMI category is associated with keloid occurrence.^{39,42} It also describes where lesions occur, what precipitated them, and how patients were treated in practice.²² Keloids are common in this equatorial Southeast Asian setting. Testing the hypothesis here allowed us to ask three questions. Can the conflicting findings in the literature be reconciled? Does general body mass discriminate keloid susceptibility? And how does local biomechanical tension relate to systemic adiposity? The novelty of this study is that it examines Asia-Pacific BMI categories in relation to keloids in an Indonesian population, in which such data are almost absent. The aim was to assess whether Asia-Pacific BMI categories are associated with keloid occurrence and to describe the anatomical sites, triggers, and treatments of keloid patients at a tertiary referral hospital in Surakarta.

2. Methods

2.1. Study design and setting

This was an observational, analytical, retrospective case-control study. It followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for case-control research.⁴⁴ Secondary archival data came from the electronic

medical record (EMR) system of the Dermatology and Venereology Outpatient Clinic at Dr. Moewardi General Hospital in Surakarta, Central Java, Indonesia. The hospital is an accredited tertiary referral and teaching hospital affiliated with the Faculty of Medicine, Universitas Sebelas Maret. It is the main referral facility for more than 6 million residents of urban, suburban, and rural areas in southern Central Java and the neighboring Special Region of Yogyakarta. The study window ran for 48 consecutive calendar months (4 full years). Every clinical encounter documented from January 1, 2022 through December 31, 2025 was eligible.

2.2. Ethical approval and patient privacy

The research protocol, data collection instruments, and confidentiality measures were approved by the Health Research Ethics Committee of Dr. Moewardi General Hospital under Document No. 931/V/HREC/2026. The study followed the World Medical Association Declaration of Helsinki and applicable Indonesian regulations on health data. Before statistical analysis, all secondary clinical and anthropometric data were de-identified and pseudonymized. Names, medical record numbers, residential addresses, and contact details were permanently deleted and replaced by alphanumeric research codes. The work was a non-interventional review of existing electronic health records, and it carried no physical, psychological, or clinical risk. The committee therefore waived individual written informed consent.

2.3. Participants and eligibility criteria

Consecutive total sampling identified and enrolled every eligible outpatient who attended the Dermatology and Venereology Clinic at Dr. Moewardi General Hospital during the 4-year period and met the predefined inclusion criteria. The final dataset had 100 subjects in two mutually exclusive groups. The case group comprised 78 patients with clinically documented keloid scars. The control group comprised 22 outpatient dermatology attendees without keloids.

The keloid case group had to meet three inclusion criteria. First, age in completed years at the first clinical evaluation had to be recorded. Second, a definitive clinical diagnosis of keloid scar had to be made by a board-certified dermatology and venereology specialist, based on characteristic morphology, and documented in the electronic medical record under International Classification of Diseases, Tenth Revision code L91.0. Third, baseline anthropometric measurements had to be complete. These were taken by trained nursing staff with calibrated stadiometers and digital medical scales. Cases were excluded if anthropometric data were missing or incomplete, if the patient was referred to an external facility before the diagnosis was confirmed, if a fibroproliferative lesion could not be conclusively distinguished as a keloid rather than a hypertrophic scar, or if an active skin neoplasm mimicked pathological scarring.

Controls were drawn by consecutive non-probability sampling of 22 outpatients seen at the same clinic over the same 4-year window (January 2022 to December 2025). Their diagnoses were benign, non-scarring, and non-fibrotic. They included superficial fungal infections (tinea corporis, tinea cruris), benign viral infection (verruca vulgaris), mild-to-moderate facial acne vulgaris without scarring, and localized allergic contact dermatitis. Complete height and weight records and a documented age, adult or pediatric, were required. A skin examination had to show no personal history or physical sign of keloid or hypertrophic scar. Using one facility and one period for recruitment was meant to limit temporal, geographic, and socioeconomic selection bias.

2.4. Anthropometric variables and BMI classification

BMI was calculated for each subject as body weight in kilograms divided by the square of height in meters (kg/m^2). Nutritional status was classified with the Asia-Pacific BMI cut-offs of the World Health Organization Western Pacific Region and Asian endocrinological consensus, which suit this Southeast Asian population.^{30,42} Four categories resulted. A BMI below $18.5 \text{ kg}/\text{m}^2$ was underweight. A BMI of 18.5 to $22.9 \text{ kg}/\text{m}^2$ was normal weight, the reference interval for Asian adults. A BMI of 23.0 to $24.9 \text{ kg}/\text{m}^2$ was overweight, indicating moderate adiposity and emerging cardiometabolic risk. A BMI of $25.0 \text{ kg}/\text{m}^2$ or higher was obese, meaning marked excess adiposity linked to systemic metabolic inflammation.

2.5. Clinical and epidemiological variables

Clinical variables were abstracted from each subject's electronic health record with a standardized form. Demographic variables were biological sex and age at presentation. Age was grouped into pediatric and adolescent, adult, and geriatric strata. Keloid sites were recorded in seven regions: the anterior trunk, lower extremities, posterior trunk, upper extremities, face, auricular structures, and genital or inguinal areas. The primary inciting injury was classified as an accidental wound, a surgical incision, severe inflammatory acne vulgaris, or unknown or spontaneous onset with no recognized preceding trauma. Treatments were grouped as intralesional triamcinolone acetonide, intralesional 5-fluorouracil, liquid nitrogen cryotherapy, surgical excision, and deferred or no intervention.

2.6. Statistical analysis

Data were compiled, verified, and analyzed with IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp.,

Armonk, NY, USA). Results were cross-checked independently with the Python libraries SciPy 1.14 and Statsmodels 0.14. Because all variables analyzed were categorical, they are summarized as frequencies (n) and percentages (%). Pearson's chi-square (χ^2) test of independence (with Yates continuity correction for 2×2 tables) examined associations between keloid occurrence and the categorical exposures (biological sex, age category, and Asia-Pacific BMI category) in 2×2 , 2×3 , and 2×4 tables. When more than 20% of cells had an expected count below 5, two-tailed Fisher's exact test (Fisher–Freeman–Halton for tables larger than 2×2) was used instead. This applied to age (2 of 6 cells) and BMI category (2 of 8 cells). Unadjusted odds ratios (OR) with 95% confidence intervals (CI) from the logit (Woolf) method expressed the strength, direction, and precision of associations. Normal weight was the reference BMI category. To control for demographic confounding and estimate each variable's contribution, we built a multivariable binary logistic regression model with the enter method. Biological sex, age category, and Asia-Pacific BMI category entered together as covariates (six coefficients for 22 control events, about 3.7 events per variable, so the model is exploratory). The model gave adjusted odds ratios (aOR) with 95% confidence intervals. Fit and calibration were assessed with the Omnibus Tests of Model Coefficients (likelihood-ratio test), the Hosmer–Lemeshow goodness-of-fit test, and Nagelkerke's pseudo- R^2 coefficient. Significance was set a priori at a two-tailed alpha of $p < 0.05$ for all tests.

3. Results

3.1. Cohort composition

Over the 4-year surveillance period, from January 2022 through December 2025, 100 outpatients met all inclusion criteria and entered the final dataset of 100 subjects. Of these, 78 (78.0%) had a clinically verified keloid scar and formed the case group. The other 22 (22.0%) attended in the same period with non-scarring skin disorders and formed the control group. Women were slightly more numerous (55.0%, $n = 55$) than men (45.0%, $n = 45$). Most subjects were adults aged 18 to 59 years (71.0%, $n = 71$). Geriatric patients aged ≥ 60 years made up 17.0% ($n = 17$), and pediatric or adolescent patients aged < 18 years made up 12.0% ($n = 12$). By Asia-Pacific BMI category, 39.0% of the cohort ($n = 39$) were normal weight. Obese subjects accounted for 27.0% ($n = 27$), overweight for 18.0% ($n = 18$), and underweight for 16.0% ($n = 16$), as shown in Table 1.

Table 1. Demographic and Anthropometric Characteristics of Keloid Patients and Non-Keloid Control Subjects (N = 100).

Characteristic	Keloid Group (n = 78)	Control Group (n = 22)	Overall Cohort (N = 100)	Statistic
Biological Sex				Yates-corrected $\chi^2 = 1.359$, df = 1, p = 0.244†
Male	38 (48.7%)	7 (31.8%)	45 (45.0%)	OR = 2.036 (95% CI: 0.748–5.539)
Female	40 (51.3%)	15 (68.2%)	55 (55.0%)	Reference
Age Category (years)				$\chi^2 = 2.378$, df = 2, p = 0.305; exact p = 0.293‡
<18 years (Pediatric / Adolescent)	9 (11.5%)	3 (13.6%)	12 (12.0%)	OR = 0.672 (95% CI: 0.160–2.834)
18–59 years (Adult)	58 (74.4%)	13 (59.1%)	71 (71.0%)	Reference (1.000)
≥60 years (Geriatric)	11 (14.1%)	6 (27.3%)	17 (17.0%)	OR = 0.411 (95% CI: 0.129–1.314)
Asia-Pacific BMI Category				$\chi^2 = 0.666$, df = 3, p = 0.881; exact p = 0.886‡
Underweight (<18.5 kg/m ²)	13 (16.7%)	3 (13.6%)	16 (16.0%)	OR = 1.300 (95% CI: 0.302–5.596)
Normal weight (18.5–22.9 kg/m ²)	30 (38.5%)	9 (40.9%)	39 (39.0%)	Reference (1.000)
Overweight (23.0–24.9 kg/m ²)	13 (16.7%)	5 (22.7%)	18 (18.0%)	OR = 0.780 (95% CI: 0.219–2.784)
Obese (≥25.0 kg/m ²)	22 (28.2%)	5 (22.7%)	27 (27.0%)	OR = 1.320 (95% CI: 0.388–4.488)

Notes: Values are n (%). BMI, body mass index; CI, confidence interval; df, degrees of freedom; OR, unadjusted odds ratio. †Pearson's χ^2 with Yates continuity correction (uncorrected $\chi^2 = 1.980$, p = 0.159; Fisher's exact p = 0.225). ‡Expected counts below 5 in more than 20% of cells; Fisher–Freeman–Halton exact p. Odds ratios and 95% CIs use the logit (Woolf) method; reference categories are female sex, age 18–59 years, and normal weight.

3.2. BMI categories in cases and controls

Among the 78 keloid patients, normal weight was the largest category (30 patients, 38.5%). Obesity came second with 22 patients (28.2%), and underweight and overweight each had 13 patients (16.7%). In the control group (n = 22), 9 subjects (40.9%) were normal weight, 5 (22.7%) overweight, 5 (22.7%) obese, and 3 (13.6%) underweight. Pearson's chi-square test on the cross-tabulation showed no significant difference in the

distribution of Asia-Pacific BMI categories between keloid patients and controls ($\chi^2 = 0.666$, degrees of freedom [df] = 3, p = 0.881; Fisher–Freeman–Halton exact p = 0.886). In the unadjusted odds ratio analysis with normal weight as the reference (1.000), obesity gave an OR of 1.320 (95% CI: 0.388–4.488, p = 0.657), underweight 1.300 (95% CI: 0.302–5.596, p = 0.725), and overweight 0.780 (95% CI: 0.219–2.784, p = 0.702). No BMI category was significantly associated with keloid occurrence, as illustrated in Figure 1.

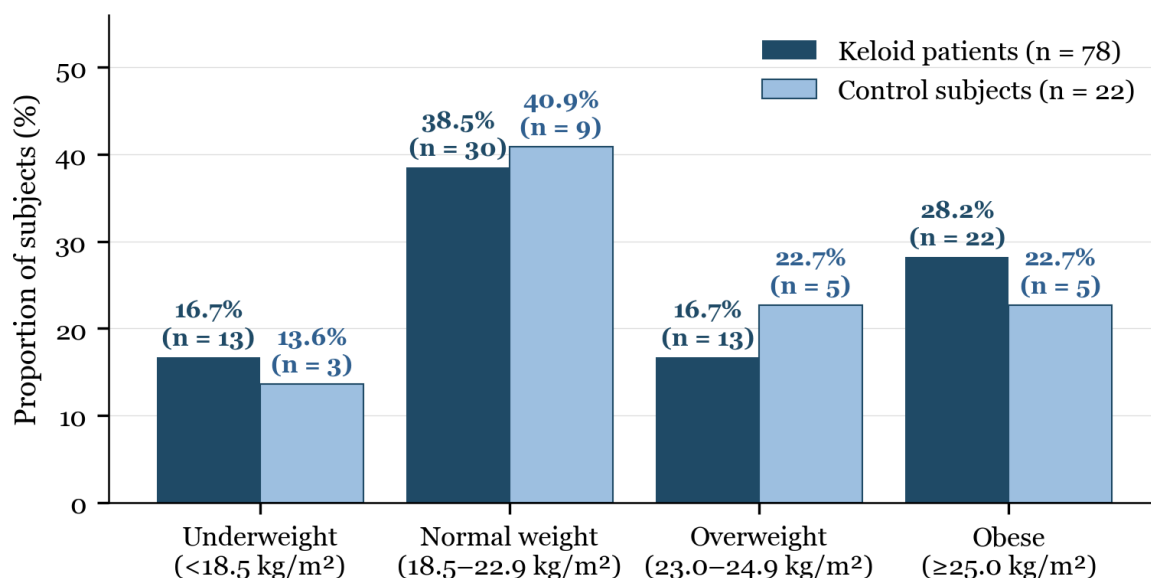


Figure 1. Comparison of body mass index (BMI) categories between keloid patients and control subjects (Pearson $\chi^2 = 0.666$, df = 3, p = 0.881; Fisher–Freeman–Halton exact p = 0.886).

3.3. Anatomical sites, triggers, and treatments

Among the 78 keloid patients, lesions were most often found at the anterior trunk and at other sites usually regarded as high-tension, as summarized in Table 2 and shown in Figure 2. Skin tension itself was not measured. The anterior trunk (pre-sternal chest, sternal notch, and pectoral areas) was the most frequent site, in 37 patients (47.4%). The lower extremity (pre-

tibial, knee, and thigh regions) was second, in 15 patients (19.2%). The posterior trunk (upper back, scapular region, interscapular area) and the upper extremities (deltoid region, brachial area, forearm) each accounted for 12 patients (15.4% each). Facial lesions (cheeks, mandibular angle, chin, perioral area) occurred in 10 patients (12.8%) and auricular keloids (ear lobule, helical rim) in 7 patients (9.0%). Genital or inguinal lesions were found in 2 patients (2.6%). Accidental skin

wounds were the most frequent documented trigger (29.5%, n = 23). Surgical incisions (28.2%, n = 22) and unknown or spontaneous onset (28.2%, n = 22) followed, and inflammatory acne vulgaris accounted for 14.1% (n = 11), as shown in Figure 3. Intralesional

triamcinolone acetonide (TAC) was given to 68 patients (87.2%), intralesional 5-fluorouracil (5-FU) to 30 (38.5%), and liquid nitrogen cryotherapy to 8 (10.3%). Active therapy was deferred in 1 patient (1.3%).

Table 2. Clinical Profiles, Anatomical Distribution, Precipitating Factors, and Therapeutic Regimens Among Keloid Patients (n = 78).

Clinical Parameter	Frequency (n)	Relative Percentage (%)	Proposed context from the literature (not measured in this study)
Anatomical Predilection Site*			
Anterior Trunk (Sternal, Pre-sternal, Pectoral)	37	47.4%	Zone of maximum repetitive cyclic respiratory shear tension
Lower Extremity (Pre-tibial, Thigh, Knee)	15	19.2%	Ambulation-induced gravitational stress and hydrostatic pressure
Posterior Trunk (Upper back, Scapular, Flank)	12	15.4%	High mechanical stretching during postural flexion/extension
Upper Extremity (Deltoid, Brachial, Forearm)	12	15.4%	High joint motility tension and post-vaccination trauma zone
Facial (Cheek, Mandibular, Perioral)	10	12.8%	Dynamic mimic muscle traction and severe acne vulgaris sequelae
Auricular (Ear lobule, Helical rim, Concha)	7	9.0%	Piercing-induced localized dermal transfixion microtrauma
Genital / Inguinal Region	2	2.6%	Frictional intertriginous shear stress and surgical incisions
Documented Precipitating Factor			
Cutaneous Wound / Accidental Laceration	23	29.5%	Mechanical barrier disruption with prolonged secondary intention repair
Surgical Incision / Operative Scar	22	28.2%	Iatrogenic dermal transection crossing resting skin tension lines
Unknown / Spontaneous Onset	22	28.2%	Microtrauma, folliculitis subclinical rupture, or genetic diathesis
Severe Inflammatory Acne Vulgaris	11	14.1%	Pilosebaceous unit rupture with persistent follicular inflammation
Recorded Therapeutic Modality*			
Intralesional Triamcinolone Acetonide (TAC)	68	87.2%	Primary standard: suppresses TGF-beta/Smad, VEGF, and fibroproliferation
Intralesional 5-Fluorouracil (5-FU) Injection	30	38.5%	Antimetabolite pyrimidine analog: induces G1/S arrest and fibroblast apoptosis
Cryotherapy (Liquid Nitrogen)	8	10.3%	Cellular microvascular thrombosis and ice-crystal stromal destruction
Untreated / No Intervention Documented	1	1.3%	Treatment refusal, deferred therapy, or diagnostic assessment only

Notes: n = 78 patients with clinically diagnosed keloid scars. *Anatomical sites and treatments were not mutually exclusive, because patients had multifocal lesions and received more than one treatment; percentages are of the total keloid group (n = 78).

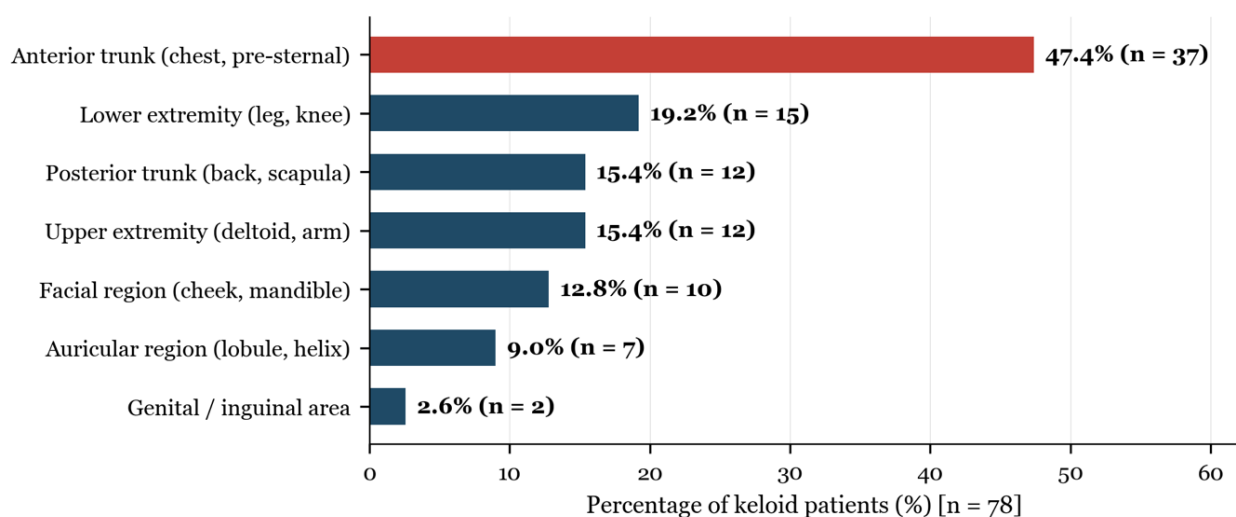


Figure 2. Anatomical site distribution among keloid patients (n = 78). Sites were not mutually exclusive.

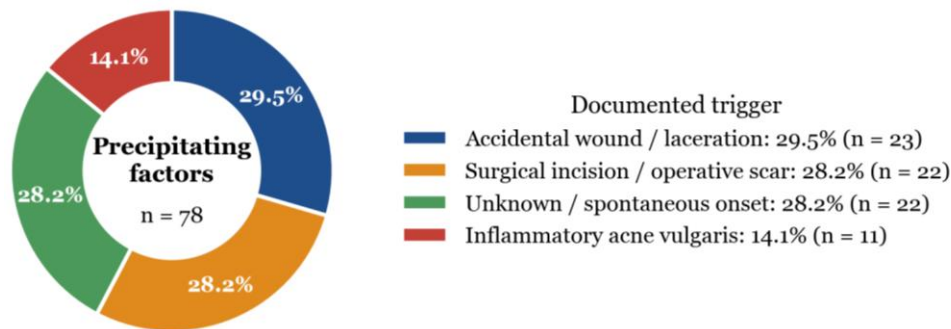


Figure 3. Documented precipitating factors in keloid patients (n = 78).

3.4. Demographic predictors and logistic regression

Sex was nearly balanced among keloid cases (51.3% female, n = 40; 48.7% male, n = 38). The control group had more women (68.2% female, n = 15; 31.8% male, n = 7). Male sex carried an unadjusted OR of 2.036 (95% CI: 0.748–5.539; continuity-corrected $\chi^2 = 1.359$, p = 0.244; uncorrected $\chi^2 = 1.980$, p = 0.159; Fisher's exact p = 0.225). By age, keloid cases were concentrated in the adult group aged 18 to 59 years (74.4%, n = 58), with 14.1% (n = 11) geriatric and 11.5% (n = 9) pediatric subjects. This did not differ significantly from the controls ($\chi^2 = 2.378$, p = 0.305; Fisher–Freeman–Halton exact p = 0.293). To estimate adjusted associations, we fitted a multivariable binary logistic regression model

with sex, age category, and Asia-Pacific BMI category together, as presented in Table 3 and Figure 4. After adjustment, BMI category remained non-significant as a predictor of keloid occurrence. The adjusted OR (aOR) was 1.412 for obese (95% CI: 0.418–4.770, p = 0.578), 1.258 for underweight (95% CI: 0.284–5.572, p = 0.763), and 0.795 for overweight (95% CI: 0.218–2.902, p = 0.728). Male sex (aOR = 2.148, 95% CI: 0.745–6.191, p = 0.157), pediatric age (aOR = 0.684, 95% CI: 0.144–3.242, p = 0.631), and geriatric age (aOR = 0.389, 95% CI: 0.121–1.248, p = 0.112) also showed no significant independent association with keloid status (Hosmer–Lemeshow $\chi^2 = 3.821$, df = 6, p = 0.701; Nagelkerke $R^2 = 0.063$).

Table 3. Binary Logistic Regression and Odds Ratio Analysis of Anthropometric and Demographic Variables for Keloid Scar Occurrence.

Explanatory variable	Unadjusted OR (95% CI)	Unadjusted p	Adjusted OR (95% CI)	Adjusted p
Biological Sex				
Female	Reference (1.000)	-	Reference (1.000)	-
Male	2.036 (0.748–5.539)	0.164	2.148 (0.745–6.191)	0.157
Age Category (years)				
18–59 years (Adult reference)	Reference (1.000)	-	Reference (1.000)	-
<18 years (Pediatric)	0.672 (0.160–2.834)	0.589	0.684 (0.144–3.242)	0.631
≥60 years (Geriatric)	0.411 (0.129–1.314)	0.134	0.389 (0.121–1.248)	0.112
Asia-Pacific BMI Category				
Normal weight (18.5–22.9 kg/m ²)	Reference (1.000)	-	Reference (1.000)	-
Underweight (<18.5 kg/m ²)	1.300 (0.302–5.596)	0.725	1.258 (0.284–5.572)	0.763
Overweight (23.0–24.9 kg/m ²)	0.780 (0.219–2.784)	0.702	0.795 (0.218–2.902)	0.728
Obese (≥25.0 kg/m ²)	1.320 (0.388–4.488)	0.657	1.412 (0.418–4.770)	0.578

Notes: OR, odds ratio; aOR, adjusted odds ratio from the multivariable binary logistic regression model with sex, age category, and BMI category entered together; CI, confidence interval. Unadjusted p-values are Wald p-values; 95% CIs use the logit method. Model: omnibus $\chi^2 = 4.412$, df = 6, p = 0.621; Nagelkerke $R^2 = 0.063$; Hosmer–Lemeshow $\chi^2 = 3.821$, df = 6, p = 0.701. The model had six coefficients for 22 control subjects and is exploratory.

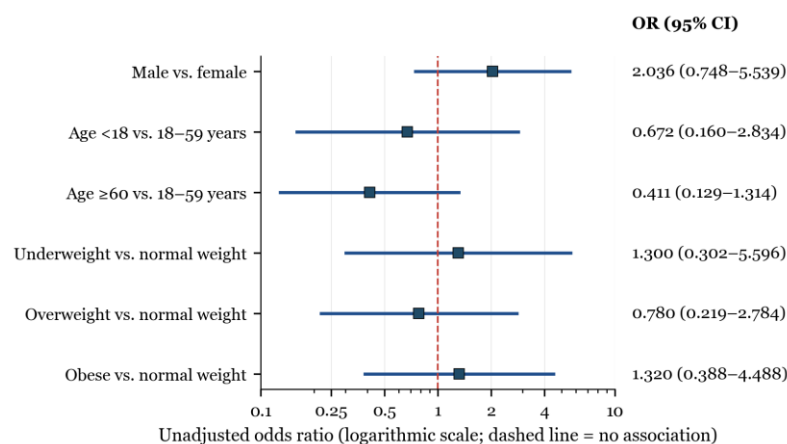


Figure 4. Forest plot of unadjusted odds ratios (OR) and 95% confidence intervals (logit method) for demographic and BMI categories in relation to keloid occurrence.

4. Discussion

4.1. Principal findings

The main finding of this case-control study was that BMI category, defined by regional Asia-Pacific thresholds, was not significantly associated with keloid occurrence ($p = 0.881$; multivariable aOR for obesity = 1.412, 95% CI: 0.418–4.770, $p = 0.578$). Among keloid cases, normal weight was the largest nutritional group (38.5%), followed by obesity (28.2%). Overweight and underweight were equally represented (16.7% each). Sex ($p = 0.244$) and age category ($p = 0.305$) also did not differ significantly between keloid patients and controls. In this sample from an Indonesian tertiary teaching center, BMI category did not discriminate keloid patients from controls, although the small control group limits precision. The finding is compatible with the view that local biomechanical tension, the wound microenvironment, and ancestral genetic predisposition matter more than overall body weight, but none of these was measured here.^{11,19,23}

4.2. Comparison with published studies

To place our findings in the published literature, we compared them with the studies in Table 4.^{22,38–41,45,46} We found no significant association between BMI category and keloid diagnosis. The published evidence is mixed. Cai et al. (2025) compared 151 keloid patients with 164 controls and found an odds ratio of 1.546 ($p = 0.077$) for a BMI of 25 kg/m² or higher, together with an association with systolic hypertension (OR = 3.859, $p = 0.024$).³⁹ Olopoenia et al. (2024) analyzed 5,457 keloid patients in United States electronic health records, and obesity was more common in keloid patients than in non-keloid cohorts ($P < 0.05$).²² In the UK Biobank, Ung et al. (2023) compared 972 people with excessive scarring with 229,106 controls and found associations with hypertension and atopic eczema.⁴⁵ Abdu Allah et al. (2019) compared 60 Egyptian keloid patients with 30 matched healthy controls, and serum interleukin-6 was higher in the keloid group (75.54 ± 39.18 vs. 19.17 ± 6.06 , $p < 0.001$).⁴¹ Our null finding for BMI category therefore differs from the US cohort and is in line with the nonsignificant odds ratio of the Chinese study, but the small control group limits any comparison.^{22,39}

Table 4. Published studies of body mass index or obesity in relation to keloids, compared with the present study.

Study (reference)	Setting and design	Sample (cases / controls)	Findings on BMI or obesity	Comment
Present study (2026)	Surakarta, Indonesia; retrospective case-control	78 keloid / 22 controls	BMI category not significantly associated with keloid occurrence ($\chi^2 p = 0.881$; obese vs. normal weight OR 1.320, 95% CI 0.388–4.488)	Small control group; limited power
Cai et al. (2025) ³⁹	China; retrospective controlled study	151 keloid / 164 controls	BMI ≥ 25 kg/m ² : OR = 1.546, $p = 0.077$; systolic hypertension: OR = 3.859, $p = 0.024$	BMI association not statistically significant
Olopoenia et al. (2024) ²²	United States; retrospective cohort, electronic health records	5,457 keloid patients and non-keloid cohorts	Obesity was more common in keloid patients ($P < 0.05$)	Differs from the null BMI result of the present study
Ung et al. (2023) ⁴⁵	United Kingdom; cross-sectional cohort (UK Biobank)	972 with keloid or hypertrophic scar / 229,106 controls	Associations with hypertension and atopic eczema; BMI not reported in the abstract	Comorbidity study; not a BMI study
Abdu Allah et al. (2019) ⁴¹	Egypt; case-control (interleukin-6 level and gene polymorphism)	60 keloid / 30 matched healthy controls	BMI was measured in all subjects; the BMI result is not stated in the abstract	Serum IL-6 higher in keloid patients (75.54 ± 39.18 vs. 19.17 ± 6.06 , $p < 0.001$)
Shi (2026) ³⁸	Letter to the editor	Not applicable	Questions whether obesity is truly a risk factor for keloid development	—
Cho et al. (2024) ⁴⁶	Distribution analysis of facial and neck keloids plus mechanical measurements in healthy volunteers	113 patients with facial or neck keloids	BMI not reported in the abstract; keloid distribution related to skin thickness and stiffness changes with movement (mandibular angle 41.3%, lateral submental 20.0%)	Context for mechanical factors; not a BMI study

Notes: Descriptive comparison of published studies of BMI or obesity and keloids. Entries marked [Author query] could not be verified against the cited source.

Where positive associations between BMI and keloids have been reported, they may depend on the population studied and on the adjustment used.^{22,39} This could explain the difference between our result and the US electronic health record cohort, in which most patients were of non-Hispanic Black, Hispanic, or Asian descent.²² Greater body mass may add mechanical stretch to existing scars on the abdomen or chest, but our data do not show that it initiates the keloid diathesis.²³

4.3. Interpretation of the BMI finding

The biological rationale linking obesity to pathological scarring rests on the endocrine and immune activity of expanded adipose tissue.^{33,34}

Hypertrophic visceral adipocytes release pro-inflammatory cytokines (TNF- α , IL-6, IL-1 β) and profibrotic adipokines, above all leptin, in high concentrations.^{34–36} In vitro and in animal models, leptin stimulates collagen type I and III synthesis, promotes dermal fibroblast chemotaxis, and upregulates TGF- β receptor expression in stromal cells.^{35,36} Adiponectin is a potent endogenous antifibrotic hormone that suppresses Smad2/3 phosphorylation and inhibits connective tissue growth factor (CTGF) transcription. Serum levels are depleted in obese individuals.^{36,37} In theory, this pro-inflammatory, hypoadiponectinemic state would prime dermal fibroblasts for uncontrolled fibroproliferation after tissue injury.^{33,35,37} Our data cannot test these mechanisms. BMI category was not

associated with keloids in this sample, which does not exclude a modest effect of adiposity.^{38,39} We offer two explanations. First, BMI is a crude measure of total body mass relative to height. It cannot separate lean muscle from fat. It cannot tell metabolically active visceral fat from subcutaneous fat either.^{31,47} In Asian populations, marked metabolic dysregulation and visceral adiposity often occur at completely normal BMI, a phenotype known as metabolically obese normal weight (MONW).^{48,49} A patient classified as normal weight by Asia-Pacific criteria (18.5–22.9 kg/m²) may therefore carry considerable visceral fat and systemic low-grade inflammation, while a muscular person classified as overweight may be metabolically healthy.^{31,47} Transcriptomic profiling shows that some profibrotic fibroblast subpopulations sustain collagen transcription independently of circulating nutritional status.^{50,51} BMI alone, then, does not capture an individual's adipokine and inflammatory profile.^{31,47,50}

Second, local mechanobiological forces are proposed in the literature as a main physical driver of keloid initiation, progression, and spread, as conceptualized in Figure 5. This study did not measure tension.^{23–25,52,53} In this study the anterior trunk was by far the most

common site, involved in 47.4% of keloid patients. The lower extremity (19.2%), posterior trunk (15.4%), and upper extremity (15.4%) followed. Breathing, thoracic movement, and changes in posture keep the pre-sternal chest and upper back under constant multidirectional cyclical tension.^{23,46} Cho et al. (2024) found that the distribution of keloids on the face and neck relates to skin thickness and stiffness changes with movement,⁴⁶ and Huang and Ogawa (2021) review the mechanical forces that promote keloid formation.¹¹ Liao et al. (2025) found higher Piezo1 levels in keloid fibroblasts, with Piezo1-mediated calcium (Ca²⁺) flux transferring the mechanosignal to YAP.²⁶ Focal adhesion kinase (FAK) and extracellular signal-regulated kinase (ERK1/2) are activated. Yes-associated protein (YAP) and transcriptional coactivator with PDZ-binding motif (TAZ) move into the nucleus.^{26,27} Mechanical tension has recently been shown to activate Engrailed-1 (En1) transcription directly in dermal fibroblasts, switching them from a pro-regenerative to a permanently profibrotic, scar-producing phenotype.²⁷ When skin in a high-tension zone is injured, this local mechanotransduction cascade can start. Excess collagen deposition could then occur whether the patient is underweight, normal weight, or obese.^{23,52,53}

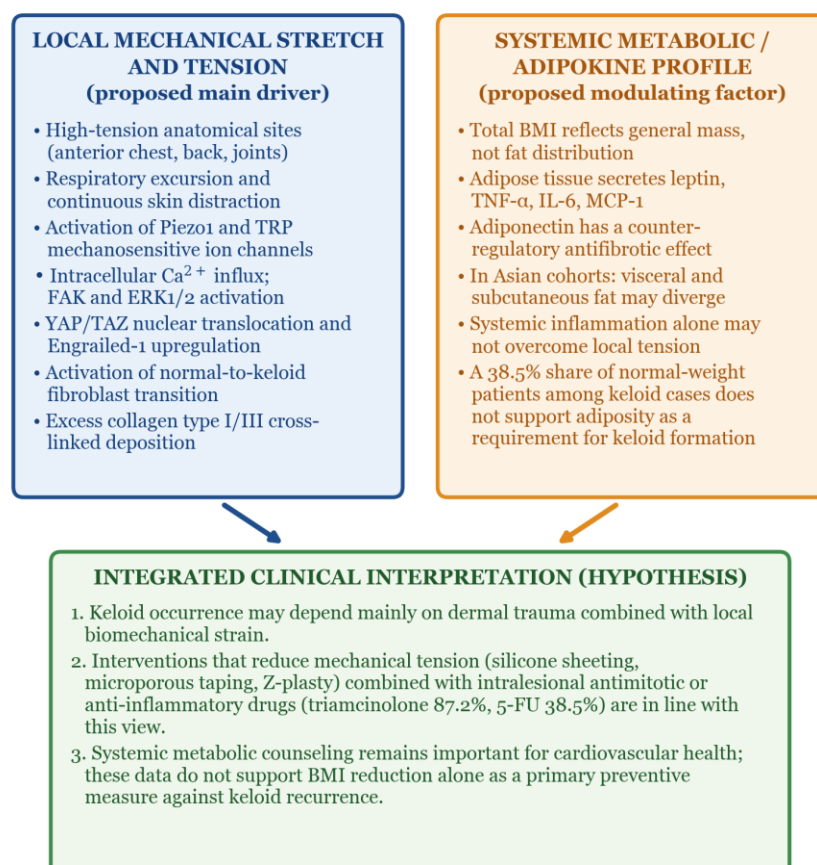


Figure 5. Conceptual framework from the literature on local mechanical tension and systemic adiposity in keloid formation. The diagram is a hypothesis and was not tested in this study.

4.4. Skin injury as a trigger

Third, the triggers documented in our cohort are compatible with the view that a break in the skin barrier initiates keloid formation.^{3,52,53} Accidental lacerations and wounds accounted for 29.5% of cases. Surgical

incisions accounted for 28.2%, and severe acne vulgaris for 14.1%. In 28.2% of patients no preceding trauma was documented. Insidious onset or forgotten minor microtrauma, such as insect bites, small abrasions, or subclinical follicular rupture, may explain this.³ In

genetically predisposed individuals, even microscopic damage to the basement membrane and reticular dermis can trigger an exaggerated influx of mast cells, M2 macrophages, and CD4⁺ T-helper 2 (Th2) lymphocytes. They secrete IL-4, IL-13, and TGF- β 1 and start a fibroproliferative loop that does not resolve.^{3,54} Whether circulating adipokines in obese patients could induce keloids in intact skin was not examined here.³

4.5. Treatment patterns

Intralesional triamcinolone acetonide (TAC) was recorded in 87.2% of keloid patients at our tertiary clinic. This reflects its established position as the first-line drug.^{55–58} Corticosteroids arrest keloid progression. They diffuse across fibroblast membranes, bind glucocorticoid receptors, and move to the nucleus, where they inhibit transcription of procollagen genes, TGF- β 1, and VEGF. They also upregulate collagenase synthesis and cause local vasoconstriction.^{6,55} TAC monotherapy is often limited by local adverse effects (skin atrophy, telangiectasia, hypopigmentation) and by scar rebound.^{6,7,58} Intralesional 5-fluorouracil (38.5%) was widely used in our cohort, an evidence-based adjunctive strategy supported by recent clinical trials.^{6,57} 5-FU, a pyrimidine antimetabolite, inhibits thymidylate synthase, arrests proliferating keloid fibroblasts in the G1/S phase, and triggers apoptosis without atrophy of the surrounding soft tissue. Combined with TAC, it has been reported to give better scar flattening and lower recurrence.^{55,57} Cryotherapy (10.3%) served as an adjuvant. It induces intracellular ice-crystal formation, microvascular thrombosis, and stromal necrosis, so deeper corticosteroid penetration becomes possible.⁵⁹

4.6. Clinical implications

The study has several clinical implications. Dermatologists and reconstructive surgeons should not assume that people of normal weight are protected from keloids, or that obesity is the main driver of recurrence.^{55,60} Risk assessment should focus on established factors: a personal or family history of keloid, darker skin phototype, high-tension anatomical sites, and the type of wound and closure.^{5,55} In surgical planning, tension-reduction techniques are essential to limit local mechanotransduction. Examples are deep subcutaneous fascial anchoring sutures, W-plasty, Z-plasty, and geometric broken-line closures that align scars along resting skin tension lines (RSTLs).^{53,60} Published guidance recommends tension-shielding measures such as silicone gel sheeting and microporous paper tape after surgery; this study did not assess treatment outcomes and cannot support a specific duration.^{56,60} Weight management and metabolic health remain important for general cardiometabolic and skin health. The present data do not support dietary weight loss alone as a way to prevent or treat keloids.^{38,55,60}

4.7. Limitations and future research

This study has several limitations. First, it was observational and retrospective, and it relied on secondary electronic medical records. Retrospective abstraction depends on how completely and accurately

routine charting was done during busy outpatient consultations. Standardized objective scar scores were not recorded systematically for all patients. These include the Vancouver Scar Scale (VSS), the Patient and Observer Scar Assessment Scale (POSAS), and high-frequency ultrasound measurement of scar thickness and dermal stiffness. This prevented correlation of BMI categories with scar volume or symptom severity.

Second, the cohort had 100 subjects (78 keloid cases and 22 dermatological controls) from one tertiary referral teaching hospital over a 4-year period. The sample may allow only large categorical differences to be detected. The control group, though, was small. The 3.5:1 case-to-control ratio reflects consecutive, fully documented records, and it may limit power to detect modest effects between intermediate BMI categories (for example, overweight versus normal weight). A single tertiary center may also introduce referral selection. Patients referred to Dr. Moewardi General Hospital often have more severe, extensive, or treatment-resistant keloids than patients managed in primary care.

Third, several biochemical and metabolic parameters were not routinely documented in the electronic records. Outpatient dermatology workups rarely include metabolic panels. The missing variables were waist circumference, waist-to-hip ratio (WHR), visceral adiposity index (VAI), homeostatic model assessment of insulin resistance (HOMA-IR), lipid profile, high-sensitivity C-reactive protein (hs-CRP), and circulating adiponectin or leptin. We could not tell metabolically healthy people from those with silent visceral adiposity and subclinical chronic inflammation within the normal weight category.

Fourth, family pedigree records, precise ancestry, genetic polymorphism screening (for example HLA alleles, NEDD4, or SMAD gene variants), and standardized longitudinal data on treatment response and recurrence were unavailable. Future research should close these gaps. A prospective, multi-center cohort design with a larger and matched control group would suit the task. It should include standardized 3D optical surface scar profilometry, direct assessment of body composition (dual-energy X-ray absorptiometry [DEXA] or bioelectrical impedance), systemic adipokine and cytokine profiling, and longitudinal tracking of treatment outcomes.

5. Conclusions

This retrospective case-control study found that BMI category, classified by standardized Asia-Pacific thresholds, was not significantly associated with keloid occurrence among dermatology outpatients at a tertiary teaching hospital in Surakarta, Indonesia. Normal weight was the most frequent category among keloid patients (38.5%), followed by obesity (28.2%). Overweight and underweight were equally represented (16.7% each). In this sample, BMI category did not discriminate keloid patients from controls, but the small control group limits precision and larger studies are needed.

In this Southeast Asian cohort, keloids were mostly located at high-tension sites, chiefly the anterior chest (47.4%). They followed a preceding skin injury or surgical trauma. These descriptive data fit current practice that emphasizes tension reduction, careful surgical closure, and intralesional triamcinolone with or without 5-fluorouracil, but the study did not evaluate treatment outcomes.

Declarations

Use of Generative Artificial Intelligence. None.

Author Contributions. A.M.: Conceptualization, Investigation, Data curation, Formal analysis, Writing – original draft. W.B.: Methodology, Validation, Supervision, Writing – review & editing. Both authors read and approved the final version of the manuscript.

Funding. None.

Conflict of Interest. The authors declare no competing financial interests, commercial affiliations, or personal conflicts of interest that could have influenced the conduct or reporting of this work.

Ethical Approval. The study received ethical clearance from the Health Research Ethics Committee (KEPK) of Dr. Moewardi General Hospital, Surakarta, Indonesia (Document No. 931/V/HREC/2026). All procedures complied with the Declaration of Helsinki.

Patient Consent. The ethics committee granted a waiver of individual written informed consent because the study was a retrospective review of de-identified electronic health records. Consent for publication is not applicable.

Data Availability. The de-identified analytical datasets generated and analyzed during the current study are available from the corresponding author upon reasonable academic request, subject to institutional review board approval and patient privacy regulations.

Acknowledgements. The authors thank the medical record staff, nursing personnel, and clinical faculty of the Department of Dermatology and Venereology at Dr. Moewardi General Hospital for their logistical support during data collection.

References

1. Chu A, Kumar S, Berthiaume F. Current therapeutic strategies and available research models for investigating hypertrophic scars. *Front Pharmacol.* 2026;17:1887685. doi:10.3389/fphar.2026.1887685
2. Berman B, Maderal A, Raphael B. Keloids and Hypertrophic Scars: Pathophysiology, Classification, and Treatment. *Dermatol Surg.* 2017;43 Suppl 1:S3-S18. doi:10.1097/DSS.0000000000000819
3. Ogawa R. Keloid and Hypertrophic Scars Are the Result of Chronic Inflammation in the Reticular Dermis. *Int J Mol Sci.* 2017;18(3):606. doi:10.3390/ijms18030606
4. Kohlhauser M, Mayrhofer M, Kamolz LP, et al. An Update on Molecular Mechanisms of Scarring-A Narrative Review. *Int J Mol Sci.* 2024;25(21):11579. doi:10.3390/ijms252111579
5. Delaleu J, Charvet E, Petit A. Keloid disease: Review with clinical atlas. Part I: Definitions, history, epidemiology, clinics and diagnosis. *Ann Dermatol Venereol.* 2023;150(1):3-15. doi:10.1016/j.annder.2022.08.010
6. Ekstein SF, Wyles SP, Moran SL, et al. Keloids: a review of therapeutic management. *Int J Dermatol.* 2021;60(6):661-671. doi:10.1111/ijd.15159
7. Frech FS, Hernandez L, Urbonas R, et al. Hypertrophic Scars and Keloids: Advances in Treatment and Review of Established Therapies. *Am J Clin Dermatol.* 2023;24(2):225-245. doi:10.1007/s40257-022-00744-6
8. Kumar SIS, Katta T, Anderson M, et al. Regional Differences in Postexcision Outcomes of Keloids: A Focus on Auricular Versus Nonauricular Sites. *Ann Plast Surg.* 2026;97(1):24-29. doi:10.1097/SAP.0000000000004775
9. Nadal JA, López-Jiménez E, Rodríguez C, et al. Immediate high-dose-rate brachytherapy with volumetric planning for keloids: Clinical outcomes. *Brachytherapy.* 2026. doi:10.1016/j.brachy.2026.07.167
10. Liu M. A panoramic analysis of keloid pathogenesis: multidimensional network regulation of genetics-immunity-metabolism-mechanical force. *Front Immunol.* 2026;17:1936809. doi:10.3389/fimmu.2026.1936809
11. Huang C, Ogawa R. Keloidal pathophysiology: Current notions. *Scars Burn Heal.* 2021;7:2059513120980320. doi:10.1177/2059513120980320
12. Yu Y, Zhu J, Ma L, et al. Endothelial system dysregulation underlies keloid development and therapeutic targeting. *Front Cell Dev Biol.* 2026;14:1919403. doi:10.3389/fcell.2026.1919403
13. Bock O, Yu H, Zitron S, et al. Studies of transforming growth factors beta 1-3 and their receptors I and II in fibroblast of keloids and hypertrophic scars. *Acta Derm Venereol.* 2005;85(3):216-20. doi:10.1080/00015550410025453
14. Helmer A, Kern J, Prohaska P, et al. Gene Expression of TGF- β 1, Matrix Metalloproteinases, and Collagen in Keloid Patients and Their Growth Patterns in 2D and 3D Cell Cultures: An In Vitro Study. *In Vivo.* 2026;40(5):2620-2634. doi:10.21873/invivo.14417
15. An Q, Li K, Gu J, et al. PLAU promotes fibroblast activation and keloid fibrogenesis through PLAUR-Dependent TGF- β /Smad signaling. *Front Immunol.* 2026;17:1855430. doi:10.3389/fimmu.2026.1855430
16. Ghazizadeh M, Tosa M, Shimizu H, et al. Functional implications of the IL-6 signaling pathway in keloid pathogenesis. *J Invest Dermatol.* 2007;127(1):98-105. doi:10.1038/sj.jid.5700564
17. Le AD, Zhang Q, Wu Y, et al. Elevated vascular endothelial growth factor in keloids: relevance to tissue fibrosis. *Cells Tissues Organs.* 2004;176(1-3):87-94. doi:10.1159/000075030
18. Aoki M, Miyake K, Ogawa R, et al. siRNA knockdown of tissue inhibitor of metalloproteinase-1 in keloid fibroblasts leads to degradation of collagen type I. *J Invest Dermatol.* 2014;134(3):818-826. doi:10.1038/jid.2013.396
19. James AJ, Torres-Guzman RA, Chaker SC, et al. Global insights into keloid formation: An international systematic review of regional genetic risk factors and commonalities. *Wound Repair Regen.* 2024;32(5):746-757. doi:10.1111/wrr.13203
20. Gwen Farm HJ, Dwivedi A, Ranjbar D, et al. The Association Between Race/Ethnicity and Keloid Formation: A Network Meta-Analysis. *Plast Surg (Oakv).* 2026;22925503261470272. doi:10.1177/22925503261470272
21. Fang X, Wang Y, Chen H, et al. Hypertrophic Scarring and Keloids: Epidemiology, Molecular Pathogenesis, and Therapeutic Interventions. *MedComm* (2020). 2025;6(10):e70381. doi:10.1002/mco2.70381
22. Olopoenia A, Yamaguchi Y, Peeva E, et al. Demographics, clinical characteristics, and treatment patterns among keloid patients: United States Electronic Health Records (EHR) Database Study. *Int J Dermatol.* 2024;63(8):e163-e170. doi:10.1111/ijd.17099
23. Ogawa R. Mechanobiology of scarring. *Wound Repair Regen.* 2011;19 Suppl 1:s2-9. doi:10.1111/j.1524-475X.2011.00707.x

24. Akaishi S, Akimoto M, Ogawa R, et al. The relationship between keloid growth pattern and stretching tension: visual analysis using the finite element method. *Ann Plast Surg.* 2008;60(4):445–51. doi:10.1097/SAP.0b013e3181238dd7
25. Huang C, Ogawa R. Fibroproliferative disorders and their mechanobiology. *Connect Tissue Res.* 2012;53(3):187–96. doi:10.3109/03008207.2011.642035
26. Liao C, Wang P, Zeng Q, et al. Piezo1-Mediated Calcium Flux Transfers Mechanosignal to Yes-Associated Protein to Stimulate Matrix Production in Keloid. *J Invest Dermatol.* 2025;145(11):2869–2881.e9. doi:10.1016/j.jid.2025.03.039
27. Mascharak S, desJardins-Park HE, Davitt MF, et al. Preventing Engrailed-1 activation in fibroblasts yields wound regeneration without scarring. *Science.* 2021;372(6540):eaba2374. doi:10.1126/science.aba2374
28. Cotterell A, Griffin M, Downer MA, et al. Understanding wound healing in obesity. *World J Exp Med.* 2024;14(1):86898. doi:10.5493/wjem.v14.i1.86898
29. Kawai T, Autieri MV, Scalia R. Adipose tissue inflammation and metabolic dysfunction in obesity. *Am J Physiol Cell Physiol.* 2021;320(3):C375–C391. doi:10.1152/ajpcell.00379.2020
30. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet.* 2004;363(9403):157–63. doi:10.1016/S0140-6736(03)15268-3
31. Gómez-Ambrosi J, Silva C, Galofré JC, et al. Body mass index classification misses subjects with increased cardiometabolic risk factors related to elevated adiposity. *Int J Obes (Lond).* 2012;36(2):286–94. doi:10.1038/ijo.2011.100
32. Tilg H, Ianiro G, Gasbarrini A, et al. Adipokines: masterminds of metabolic inflammation. *Nat Rev Immunol.* 2025;25(4):250–265. doi:10.1038/s41577-024-01103-8
33. Ouchi N, Parker JL, Lugus JJ, et al. Adipokines in inflammation and metabolic disease. *Nat Rev Immunol.* 2011;11(2):85–97. doi:10.1038/nri2921
34. Fain JN. Release of interleukins and other inflammatory cytokines by human adipose tissue is enhanced in obesity and primarily due to the nonfat cells. *Vitam Horm.* 2006;74:443–77. doi:10.1016/S0083-6729(06)74018-3
35. Seleit I, Bakry OA, Samaka RM, et al. Immunohistochemical Evaluation of Leptin Expression in Wound Healing: A Clue to Exuberant Scar Formation. *Appl Immunohistochem Mol Morphol.* 2016;24(4):296–306. doi:10.1097/PAL.0000000000000187
36. Buechler C, Haberl EM, Rein-Fischboeck L, et al. Adipokines in Liver Cirrhosis. *Int J Mol Sci.* 2017;18(7):1392. doi:10.3390/ijms18071392
37. Ma L, Li X, Bai Z, et al. AdipoRs- a potential therapeutic target for fibrotic disorders. *Expert Opin Ther Targets.* 2019;23(2):93–106. doi:10.1080/14728222.2019.1559823
38. Shi X. Is Obesity Truly a Risk Factor for Keloid Development? *Aesthetic Plast Surg.* 2026;50(5):2193–2194. doi:10.1007/s00266-025-05400-y
39. Cai Y, Ye Y, Wang Z, et al. Association of Keloid with Body Mass Index and Hypertension: A Retrospective Controlled Study. *Aesthetic Plast Surg.* 2025;49(19):5335–5340. doi:10.1007/s00266-025-05102-5
40. Rutherford A, Glass DA. A case-control study analyzing the association of keloids with hypertension and obesity. *Int J Dermatol.* 2017;56(9):e187–e189. doi:10.1111/ijd.13618
41. Abdu Allah AMK, Mohammed KI, Farag AGA, et al. Interleukin-6 serum level and gene polymorphism in keloid patients. *Cell Mol Biol (Noisy-le-grand).* 2019;65(5):43–48. doi:10.14715/cmb/2019.65.5.7
42. Misra A. Ethnic-Specific Criteria for Classification of Body Mass Index: A Perspective for Asian Indians and American Diabetes Association Position Statement. *Diabetes Technol Ther.* 2015;17(9):667–71. doi:10.1089/dia.2015.0007
43. Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev.* 2002;3(3):141–6. doi:10.1046/j.1467-789x.2002.00065.x
44. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol.* 2008;61(4):344–9. doi:10.1016/j.jclinepi.2007.11.008
45. Ung CY, Warwick A, Onoufriadis A, et al. Comorbidities of Keloid and Hypertrophic Scars Among Participants in UK Biobank. *JAMA Dermatol.* 2023;159(2):172–181. doi:10.1001/jamadermatol.2022.5607
46. Cho H, Dohi T, Wakai H, et al. In the face and neck, keloid scar distribution is related to skin thickness and stiffness changes associated with movement. *Wound Repair Regen.* 2024;32(4):419–428. doi:10.1111/wrr.13180
47. Müller MJ, Braun W, Enderle J, et al. Beyond BMI: Conceptual Issues Related to Overweight and Obese Patients. *Obes Facts.* 2016;9(3):193–205. doi:10.1159/000445380
48. Sruthi KG, Aditya C, Panda P, et al. Prevalence of normal weight obesity among adults in Southeast Asia: Insights from a systematic review and meta-analysis. *Metabol Open.* 2025;28:100416. doi:10.1016/j.metop.2025.100416
49. Ruderman NB, Schneider SH, Berchtold P. The "metabolically-obese," normal-weight individual. *Am J Clin Nutr.* 1981;34(8):1617–21. doi:10.1093/ajcn/34.8.1617
50. Deng CC, Hu YF, Zhu DH, et al. Single-cell RNA-seq reveals fibroblast heterogeneity and increased mesenchymal fibroblasts in human fibrotic skin diseases. *Nat Commun.* 2021;12(1):3709. doi:10.1038/s41467-021-24110-y
51. Liu X, Chen W, Zeng Q, et al. Single-Cell RNA-Sequencing Reveals Lineage-Specific Regulatory Changes of Fibroblasts and Vascular Endothelial Cells in Keloids. *J Invest Dermatol.* 2022;142(1):124–135.e11. doi:10.1016/j.jid.2021.06.010
52. Huang C, Liu L, You Z, et al. Keloid progression: a stiffness gap hypothesis. *Int Wound J.* 2017;14(5):764–771. doi:10.1111/iwj.12693
53. Ogawa R, Akaishi S, Huang C, et al. Clinical applications of basic research that shows reducing skin tension could prevent and treat abnormal scarring: the importance of fascial/subcutaneous tensile reduction sutures and flap surgery for keloid and hypertrophic scar reconstruction. *J Nippon Med Sch.* 2011;78(2):68–76. doi:10.1272/jnms.78.68
54. Chen Q, Wan S, Duan Y, et al. Immune Imbalance Drives Keloid Pathogenesis: Emerging Targets for Precision Immunotherapy. *Adv Wound Care (New Rochelle).* 2026;21621918261417702. doi:10.1177/21621918261417702
55. Ogawa R. The Most Current Algorithms for the Treatment and Prevention of Hypertrophic Scars and Keloids: A 2020 Update of the Algorithms Published 10 Years Ago. *Plast Reconstr Surg.* 2022;149(1):79e–94e. doi:10.1097/PRS.0000000000000867
56. Mustoe TA, Cooter RD, Gold MH, et al. International clinical recommendations on scar management. *Plast Reconstr Surg.* 2002;110(2):560–71. doi:10.1097/00006534-200208000-00031
57. Hietanen KE, Järvinen TA, Huhtala H, et al. Treatment of keloid scars with intralesional triamcinolone and 5-fluorouracil injections - a randomized controlled trial. *J Plast Reconstr Aesthet Surg.* 2019;72(1):4–11. doi:10.1016/j.bjps.2018.05.052
58. Shao Y, Hu J, Li Y, et al. Predicting corticosteroid resistance and recurrence in keloids: a machine learning study integrating dermatoscopy and ultrasound. *Front Med*

- (Lausanne). 2026;13:1925984. doi:10.3389/fmed.2026.1925984
59. van Leeuwen MCE, van der Wal MBA, Bulstra AJ, et al. Intralesional cryotherapy for treatment of keloid scars: a prospective study. *Plast Reconstr Surg.* 2015;135(2):580–589. doi:10.1097/PRS.0000000000000911
60. Monstrey S, Middelkoop E, Vranckx JJ, et al. Updated scar management practical guidelines: non-invasive and invasive measures. *J Plast Reconstr Aesthet Surg.* 2014;67(8):1017–25. doi:10.1016/j.bjps.2014.04.011