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Forgotten Skin: What do our geriatric patch test findings reveal?

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Abstract
Allergic contact dermatitis (ACD) in the elderly is influenced by age-related immunological changes, cumulative exposure, and skin barrier alterations. However, data comparing sensitization profiles among different geriatric populations remains limited. We aimed to evaluate and compare the patterns and severity of patch test reactions in patients aged 65-74 (young-old group) and those aged 75 years or older (old-old group), using the European Standard Series (ESS). A total of 128 patients aged 65 years or older were retrospectively analyzed. Patch testing was performed with the ESS, and reactions were assessed at 48 and 96 hours according to the International Contact Dermatitis Research Group (ICDRG) criteria. Of the patients, 106 were classified as young-old and 22 as old-old. The most frequent allergens in the young-old group were propolis (20%), fragrance mix I (17%), methyldibromo glutaronitrile (16%), peru balsam (15.1%), and nickel sulfate (14.2%), while methylchloroisothiazolinone/methylisothiazolinone (22.7%), methylisothiazolinone (13.6%), propolis (13.6%), and textile dye mix (13.6%) were the most common that in the old-old group. Across both groups, preservative and fragrance-related allergens predominated. According to ICDRG grading, most reactions were weak positive (+), whereas moderate positive (++) and strong positive (+++) reactions were less frequent, particularly in the old-old group. In conclusion, preservatives, propolis and fragrance-related allergens remain the leading causes of contact sensitization in the elderly, while metal sensitization decreases with advancing age. The reduced frequency and intensity of positive reactions in the old-old group may reflect immunosenescence and diminished T-cell responsiveness in advanced age.

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Introduction

Contact dermatitis (CD) is an inflammatory skin reaction that occurs following exposure to an external substance, typically characterized by itching, erythema, vesiculation, scaling, or fissuring of the skin. It is broadly classified into two types: irritant contact dermatitis (ICD) and allergic contact dermatitis (ACD).[1] ICD results from the direct cytotoxic effect of chemical or physical agents on the skin barrier and does not involve an immunologic mechanism. Common irritants include soaps, detergents, cleaning agents, disinfectants, and various industrial chemicals. This form is most frequently observed on the hands and generally resolves rapidly after discontinuation of exposure to the irritant.[2] In contrast, ACD is a type IV delayed-type hypersensitivity reaction mediated by the immune system. In this condition, a low-molecular-weight substance (hapten) penetrates the epidermis, binds to skin proteins, and elicits sensitization of T lymphocytes. Upon reexposure, these sensitized T cells trigger an inflammatory response leading to pruritic, erythematous, and sometimes vesicular lesions. The most frequently implicated allergens include nickel, cobalt, chromium, fragrances, cosmetics, rubber accelerators, and certain topical medications.[1,3,4]

The diagnosis of CD is established through a careful assessment of clinical findings, a detailed evaluation of the patient's history, and, when necessary, the use of supplementary diagnostic tests. The most critical step in the diagnostic process involves determining the location of the lesions, their temporal relationship with potential exposures, and any relevant contact history. When the ACD is suspected, a patch test is performed to confirm the diagnosis. Patch testing is regarded as the gold standard method for detecting delayed-type hypersensitivity reactions to contact allergens. In this procedure, selected allergens are applied to the patient's upper back in standardized concentrations and occluded for 48 h. The test sites are then evaluated at 48–96 h for erythema, edema, papules, or vesicles, which indicate sensitization to specific allergens. Standardized allergen panels, such as the European Standard Series (ESS), are commonly used to identify the most prevalent sensitizers.[5–8] The ESS panel contains common allergens, such as nickel sulphate, cobalt chloride, potassium dichromate, a fragrance mix, peru balsam, neomycin sulphate, and formaldehyde.[7,8]

The CD is a significant clinical problem in terms of diagnosis and management, particularly among the elderly.[9–11] Age-related changes in immune response, epidermal barrier function and skin physiology during the geriatric period may affect the development of contact sensitization and reactions to irritants. As we age, the lipid content in the epidermis decreases, the stratum corneum thins, and the rate of transepidermal water loss increases. This leads to impaired barrier function and altered sensitivity to irritants.[9,10,12,13] Additionally, it has been reported that the rates of sensitization in elderly individuals may differ from those in young adults, due to weakened cellular immune responses (immunosenescence) and decreased lymphocyte proliferation capacity.[14–17] However, factors such as polypharmacy, chronic disease prevalence, topical medication use, and increased exposure to personal care products further complicate the diagnosis and treatment of CD in older individuals. Therefore, the sensitivity of patch testing, positive reaction rates, and allergen distribution may differ in the geriatric population.[18–21]

Studies on patch tests in elderly individuals are limited in the literature, and there are significant differences in the results. While some studies report a decrease in positive test rates with age, others emphasize the sensitivity to metals and topical medications in elderly patients.[8,9,14,15,21] It is believed that these differences stem from variables such as test application protocols, allergen series, geographical factors, and patient profiles.

There are very few studies from Turkey that retrospectively evaluate the results of the ESS patch test in the geriatric population. However, the proportion of elderly individuals in our country is steadily increasing, and the burden of chronic dermatological and allergic diseases is rising in parallel with this demographic shift.[21–23] In this context, the identification of allergens that most commonly cause sensitivity in elderly individuals is of clinical importance for the development of appropriate prevention and treatment strategies.

Aim

This study aims to retrospectively evaluate the results of the ESS patch test in the geriatric population to determine the rates of positive reactions and the distribution of allergens. In addition, it investigates the relationship between test results and factors such as age, gender, and accompanying dermatological diagnoses. The findings are expected to enhance our understanding of the epidemiological characteristics of contact sensitization in elderly individuals in our country and to support the development of future preventive strategies.

Materials and Methods

Study design

Between January 2019 and September 2025, the ESS patch test results of geriatric patients who presented to the Immunology and Allergic Diseases Clinic with suspected ACD were retrospectively evaluated in accordance with the tenets of the Declaration of Helsinki after receiving approval from the local ethics committee of Ankara Bilkent City Hospital (Approval number: TABED 1-25-1798). Patients aged 65 years or older, who had completed the patch test procedure with fully documented results, were included in the study.

Exclusion criteria comprised individuals younger than 65 years, those with incomplete or insufficient test records, and patients receiving systemic immunosuppressive therapy such as corticosteroids, cyclosporine, or methotrexate.

Data collection

Demographic data (age and gender) and clinical diagnoses of the patients were recorded from their files, as were test indications, concomitant systemic diseases

(e.g., hypertension, diabetes and malignancy), and medication use.

Patients were classified into subgroups according to age to account for heterogeneity within the geriatric population. Patients aged 65–74 years were categorized as the "young-old" group, those aged 75–84 years as the "old-old" group, and those aged 85 years and older as the "oldest-old" or "very old" group. This classification was used to facilitate age-specific comparisons in clinical characteristics and test results.[24,25]

Patch test procedure and evaluation

Patch testing was performed using the ESS, comprising 30 allergens (Chemotechnique Diagnostics, Vellinge, Sweden). The allergen patches were applied to clean, dry skin on both sides of the upper back, adjacent to the midline. Following the application, the test area was kept dry, and patients were instructed to avoid activities that could cause excessive sweating or friction.[7,8,23]

Patch test readings were performed in accordance with the International Contact Dermatitis Research Group (ICDRG) criteria.[26] The first assessment was conducted 48 h after the removal of the test patches, and the second assessment was performed at 96 h. Reactions were classified based on the severity of clinical findings: negative (−); questionable (? or ±), indicating erythema or mild infiltration; weak positive (+), characterized by erythema, papules, and mild vesicles; moderate positive (++), showing erythema, papules, and vesicles; strong positive (+++), with widespread erythema, edema, and bullous lesions; and irritant reactions (IR), defined as non-allergic, polymorphic lesions. In this study, only allergic positive reactions (+, ++, +++) were included in the analysis.[26,27] Patch test results were recorded according to international standards, and all tests were performed using the same procedure in the same clinic.

Statistical analysis

Data analysis was performed using the SPSS 11.5 for Windows software package (SPSS Inc., Chicago, IL, USA). Descriptive statistics for nominal data are presented as counts and percentages, and quantitative data are presented either as mean ± standard deviations or medians and minimum–maximum depending on assumptions of normality based on visual (histograms and probability graphs) and analytical methods (Kolmogorov–Smirnov and Shapiro-Wilk tests). The Chi-square or Fisher's exact test was used to compare categorical variables, as appropriate. P-values below 0.05 were considered significant.

Results

General specialties of the study population

A total of 128 patients were included in the study, comprising 106 individuals in the "young-old" group (65–74 years) and 22 in the "old-old" group (≥75 years). There was only one patient aged over 85 years, and this patient was included in the "old-old" group. There was no significant difference between the two groups in terms of sex distribution (P = 0.883). Regarding occupation, the majority of participants in both groups were housewives or retired, with no significant difference observed between the groups (P = 0.552). Similarly, the prevalence of comorbidities—including cardiovascular, endocrine, rheumatologic diseases, and malignancy—did not differ significantly between the groups (P = 0.818). Occupational exposure was reported in seven patients (6.6%) in the young-old group, while no such exposure was observed among the old-old patients; however, this difference was not statistically significant (P = 0.603). In terms of the site of dermatitis, the hands were the most frequently involved area in both groups, and the distribution of body areas affected was comparable between them (P = 0.947). Likewise, there was no significant difference in the pattern of involvement (localized versus diffuse) between the young-old and old-old groups (P = 0.601). Detailed demographic and clinical characteristics of the study population are presented in Table 1.

Table 1 Comparison of demographic and clinical characteristics between the young-old and old-old groups.

Features	Young-old group (n = 106)	Old-old group (n = 22)	P
Sex (n [%])			
Female	50 (47.2)	10 (45.5)	0.883
Male	56 (52.8)	12 (54.5)	
Age (years) (median [min-max])	69 (65-74)	77 (75-92)	0.001
Occupation (n [%])			
Housewife	43 (40.6)	9 (40.9)	NA*
Retired	54 (50.9)	13 (59.1)	
Civil servant	4 (3.8)	0*	
Employee	5 (4.7)	0*	
Comorbidities (n [%])			
Cardiovascular	61 (57.5)	14 (63.6)	0.818
Endocrine	27 (25.5)	4 (18.2)	
Rheumatological	10 (9.5)	2 (9.1)	
Malignancy	8 (7.5)	2 (9.1)	
Occupational exposure (n [%])			
Yes	7 (6.6)	0*	NA*
No	99 (93.4)	22 (100)	
Body area (n [%])			
Hand	53 (50)	11 (50)	0.947
All body	35 (33)	6 (27.3)	
Face	12 (11.3)	3 (13.6)	
Foot	6 (5.7)	2 (9.1)	
Involvement (n [%])			
Local	71 (67)	16 (72.7)	0.601
Diffuse	35 (33)	6 (27.3)	

min (minimum), max (maximum). *P values were not calculated for variables containing zero cell counts.

Evaluation of 48th and 96th hours ESS patch test results

The comparison of patch test results between the young-old (65–74 years, n = 106) and old-old (≥75 years, n = 22) groups revealed several differences in allergen sensitization patterns.

In the young-old group, the most frequent positive reactions at the 96th-hour reading were observed with propolis (n = 21, 20%), fragrance mix I (n = 18, 17%), methyldibromo glutaronitrile (n = 17, 16%), peru balsam (n = 16, 15.1%), nickel sulfate (n = 15, 14.2%), formaldehyde (n = 13, 12.3%), and methylchloroisothiazolinone/methylisothiazolinone (MI/MCI) (n = 13, 12.3%).

Other common sensitizers included methylisothiazolinone (n = 11, 10.4%) and fragrance mix II (n = 4, 3.8%), reflecting a predominance of reactions to preservatives and fragrance-related allergens. Moderate positivity was also seen with colophonium, budesonide, and cobalt chloride, while isolated single reactions occurred with paraben mix, lanolin alcohol, textile dye mix, and epoxy resin. No positive responses were detected for -tert-Butylphenol-formaldehyde resin (PTBP-FR), N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), or mercapto mix in the young-old group.

In the old-old group, although the overall frequency of positive reactions was lower, certain allergens produced notable sensitization. The most common reactions were observed to MI/MCI (n = 5, 22.7%), followed by methylisothiazolinone (n = 3, 13.6%), propolis (n = 3, 13.6%), and textile dye mix (n = 3, 13.6%). Other allergens eliciting positive responses included para-phenylenediamine (n = 2, 9.1%), mercaptobenzothiazole (n = 2, 9.1%), epoxy resin (n = 2, 9.1%), paraben mix (n = 2, 9.1%), nickel sulfate (n = 2, 9.1%), and peru balsam (n = 2, 9.1%). Reactions to formaldehyde (n = 1, 4.5%), 2-hydroxyethyl methacrylate (n = 1, 4.5%), and H3CC (hydroxyisohexyl 3-cyclohexene carboxaldehyde) (n = 1, 4.5%) were also noted. No positive reactions were detected to thiuram mix, colophonium, sesquiterpene lactone mix (SLM), or mercapto mix in this group. The detailed ESS patch test results are presented in Table 2.

Positive patch test results at the 96-hour stage

The majority of positive reactions observed in the young-old group were graded as weak positive (+). Moderate positive (++) and strong positive (+++) reactions were observed less frequently. Among the tested allergens, nickel sulfate, fragrance mix I, and propolis were the leading sensitizers responsible for stronger (++ or +++) reactions. In contrast, reactions to other allergens such as potassium dichromate, thiuram mix, and neomycin sulfate were predominantly weak. The pattern of sensitization suggests that metal allergens and fragrance-related compounds remain the most frequent causes of ACD in this age group. The positive patch test results at the 96-hour stage in the young-old group, according to the criteria of the ICDRG are presented in Figure 1.

In the old-old group, the majority of observed reactions were weak positive (+), while moderate positive (++) and strong positive (+++) reactions were rarely encountered. The most common sensitizers in this group were nickel sulfate, MI/MCI, methylisothiazolinone, propolis, and textile dye mix. Among these, MI/MCI and propolis occasionally elicited stronger (++ or +++) responses, suggesting a relatively higher sensitization potential. Other allergens such as para-phenylenediamine, formaldehyde, and peru balsam produced only weak positive reactions. Overall, the pattern of sensitization in the old-old group demonstrated a predominance of preservative and fragrance-related allergens, whereas reactions to metals were less frequent compared with the young-old group. The positive patch test results at the 96-hour stage in the old-old group, according to the criteria of the ICDRG is presented in Figure 2.

Discussion

Our study provides a detailed assessment of contact allergen sensitization patterns among elderly patients, with a focus on comparing the young-old and old-old subgroups. Despite the immunological changes (immunosenescence) that are associated with the process of aging, the findings of this study demonstrate that ACD continues to be a clinically important condition within this demographic.[9,15]

In both subgroups, the hands were the area most commonly affected, which is consistent with previous reports that identified manual activities, wet work and daily household exposures as major risk factors for CD in elderly patients.[28-30] The high proportion of housewives and retired people in both groups suggests that nonoccupational exposure, particularly to personal care products, topical medications, and household agents, plays a significant role in allergen sensitization later in life.[15,31]

The overall allergen distribution exhibited both similarities and differences between the subgroups. In the young-old group, the leading sensitizers were propolis, fragrance mix I, methyldibromo glutaronitrile, peru balsam, nickel sulfate, and formaldehyde. These findings are consistent with those of earlier European and Asian studies, which identified fragrance and preservative components as frequent contributors to ACD in the geriatric population.[17,21,32-35] Nickel sulfate, a well-documented allergen in younger demographics, was identified as a prevalent sensitizer in our cohort. This observation is indicative of a cumulative exposure over an individual's lifetime, likely attributable to frequent contact with jewellery, metal objects, and household utensils.[36-39]

In our study, propolis was identified as one of the most prevalent sensitizing agents in the young-old group, occupying a prominent position among the top allergens associated with positive patch test reactions. This finding emphasizes the mounting clinical significance of propolis-related ACD in the elderly population. Propolis, a natural resinous substance collected by honeybees from plant buds, is widely used in cosmetics, pharmaceuticals, and "natural" therapeutic products due to its antimicrobial, anti-inflammatory, and antioxidant properties. Nevertheless, the intricate chemical composition of this substance, which encompasses caffeic acid esters, cinnamic acid derivatives, flavonoids, and phenolic compounds, renders it a highly efficacious sensitizer, capable of inducing ACD.[40-43]

The relatively high frequency of propolis sensitization in our cohort may be indicative of increased exposure through

Table 2 Frequency of positive patch test reactions at 48 and 96 h according to age group.

Allergen	Young-old group (n = 106)	Old-old group (n = 22)	Allergen	Young-old group (n = 106)	Old-old group (n = 22)
Potassium dichromate, n (%)*			PTBP-FR, n (%)*		
48th	2 (1.9)	0	48th	0	0
96th	2 (1.9)	0	96th	0	0
Para-phenylenediamine, n (%)*			Mercaptobenzothiazole, n (%)*		
48th	0	0	48th	0	0
96th	1 (0.9)	2 (9.1)	96th	0	2 (9.1)
Thiuram mix, n (%)*			Formaldehyde, n (%)*		
48th	4 (3.8)	0	48th	4 (3.8)	1 (4.5)
96th	4 (3.8)	0	96th	13 (12.3)	1 (4.5)
Neomycin sulfate, n (%)*			Fragrance mix I, n (%)*		
48th	0	0	48th	9 (8.5)	0
96th	1 (0.9)	0	96th	18 (17)	0
Cobalt chl. hexahydrate, n (%)			SLM, n (%)*		
48th	2 (1.9)	0	48th	1 (0.9)	0
96th	4 (3.1)	0	96th	1 (0.9)	0
Caine mix, n (%)*			Quaternium-15, n (%)*		
48th	0	0	48th	0	0
96th	2 (1.6)	0	96th	0	0
Nickel sulfate hexahydrate, n (%)*			Propolis, n (%)*		
48th	7 (6.6)	2 (9.1)	48th	6 (5.7)	1 (4.5)
96th	15 (14.2)	2 (9.1)	96th	21 (20)	3 (13.6)
2-Hydroxyethyl methacrylat, n(%)*			MI/MCI, n (%)*		
48th	0	0	48th	4 (3.8)	0
96th	3 (2.8)	1 (4.5)	96th	13 (12.3)	5 (22.7)
Colophonium, n (%)*			Budesonide, n (%)*		
48th	3 (2.8)	0	48th	2 (1.9)	0
96th	4 (3.8)	0	96th	3 (2.8)	0
Paraben mix, n (%)*			Tixocortol -21-pivalate, n (%)		
48th	0	0	48th	1 (0.9)	0
96th	1 (0.9)	2 (9.1)	96th	1 (0.9)	0
IPPD, n (%)*			Methyldibromo glutaronitrile, n (%)*		
48th	0	0	48th	6 (5.7)	0
96th	0	0	96th	17 (16)	0
Lanolin alcohol, n (%)*			Fragrance mix II, n (%)*		
48th	1 (0.9)	0	48th	1 (0.9)	0
96th	1 (0.9)	0	96th	4 (3.8)	0
Mercapto mix, n (%)*			H3CC, n (%)*		
48th	0	0	48th	1 (0.9)	1 (4.5)
96th	0	0	96th	1 (0.9)	1 (4.5)
Epoxyresin, n (%)*			Methylisothiazolinone, n (%)*		
48th	0	0	48th	1 (0.9)	1 (4.5)
96th	1 (0.9)	2 (9.1)	96th	11 (10.4)	3 (13.6)
Peru Balsam, n (%)*			Textile dye mix, n (%)*		
48th	8 (7.5)	0	48th	1 (0.9)	1 (4.5)
96th	16 (15.1)	2 (9.1)	96th	2 (1.9)	3 (13.6)

*Values show the number of positive cases (n) and the percentage (%) of positive cases in groups.
No statistical comparisons were performed due to the small sample size and zero cell counts.
Hydroxyisohexyl 3-cyclohexene carboxaldehyde (H3CC), Methylisothiazolinone (MI), methylchloroisothiazolinone (MCI), N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), 4-tert-Butylphenol-formaldehyde resin (PTBP-FR), Sesquiterpene lactone mix (SLM).

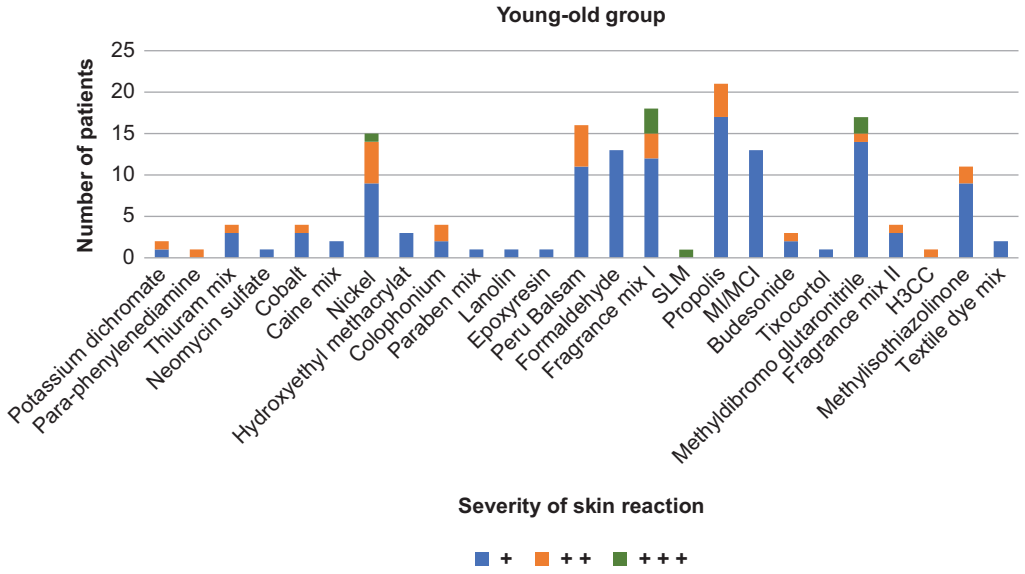

Figure 1 Patch test results in the young-old group according to the International Contact Dermatitis Research Group criteria. Hydroxyisohexyl 3-cyclohexene carboxaldehyde (H3CC), Methylisothiazolinone (MI), methylchloroisothiazolinone (MCI), N-isopropyl-N'-phenyl-p-phenylenediamine (IPPD), 4-tert-Butylphenol-formaldehyde resin (PTBP-FR), Sesquiterpene lactone mix (SLM).

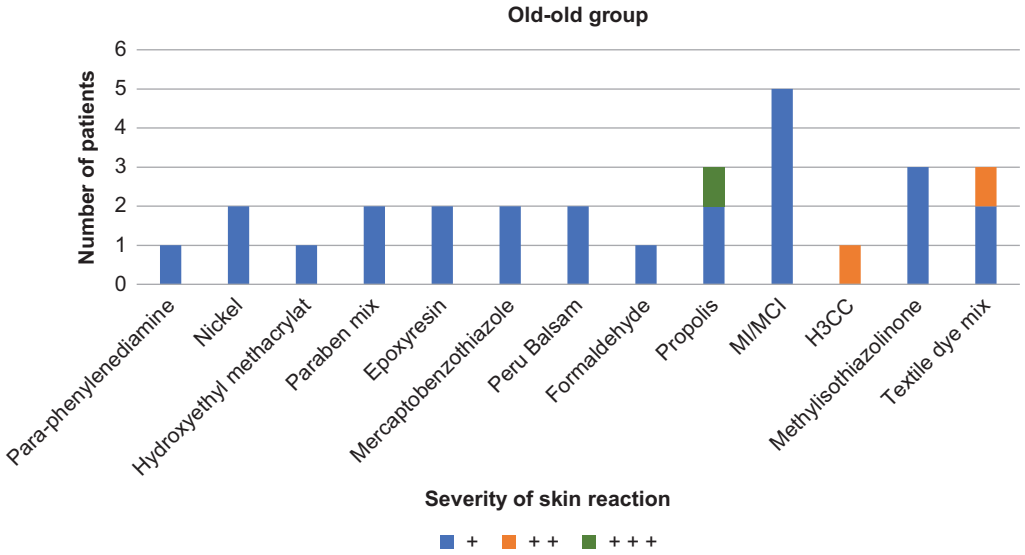

Figure 2 Patch test results in the old-old group according to the International Contact Dermatitis Research Group criteria. Hydroxyisohexyl 3-cyclohexene carboxaldehyde (H3CC), Methylisothiazolinone (MI), methylchloroisothiazolinone (MCI).

topical formulations, such as wound-healing creams, lip balms, and herbal ointments that are commonly used by older adults. In Turkey and other countries, propolis-containing natural products have become increasingly available without prescription, contributing to inadvertent sensitization, especially among patients with chronic skin conditions who apply these agents repeatedly.[44-46] In addition, the utilization of propolis-based products has seen a significant escalation in recent times, coinciding with the advent of the pandemic caused by the severe acute respiratory syndrome (SARS-CoV-2) virus. This increased utilization can be attributed to the perceived medicinal properties of propolis, namely its antiviral, anti-inflammatory, and immune-boosting characteristics. During this period, propolis was commonly marketed as a "natural immune enhancer," available in various formulations such as oral supplements, throat sprays, lozenges, and topical preparations. This surge in utilization was especially pronounced among middle-aged and elderly individuals, who sought natural methods of preventing infection and enhancing immune function during the pandemic.[47-49]

In our study, in contrast to the young-old group, the old-old group demonstrated a reduced frequency of positive patch test reactions, a finding that aligns with the

concept of immunosenescence and reduced T-cell responsiveness in advanced age.[14,15] Nonetheless, MI/MCI, methylisothiazolinone, and textile dye mix were identified as prominent sensitizers in this group. It has been hypothesized that higher rates of isothiazolinone sensitization may be associated with ongoing exposure to leave-on and rinse-off products, given the continued utilization of these preservatives in a wide range of cosmetics and hygiene products.[50-52] In addition, sensitization to textile dye mixes was prevalent in the old-old group in our cohort. This may be due to prolonged skin contact with textiles, which is associated with the reduced ability of older skin to restore its barrier function.[53] These results highlight that although the overall frequency of sensitization may decline with age, certain allergens—particularly preservatives and natural extracts—retain high sensitization potential even in advanced age.[54]

Altogether, this study revealed that ACD remains a significant health concern for the elderly, with propolis, fragrance-related substances, preservatives and metals emerging as the primary allergens. Similar distributions of dermatitis sites and clinical patterns were observed in the young-old and old-old groups, indicating that the clinical presentation of ACD is not substantially altered by chronological ageing alone, although the strength and diversity of sensitization may vary.

Our study has several notable strengths. First, it focuses specifically on the geriatric population, a group often underrepresented in research on ACD, and further stratifies participants into young-old and old-old subgroups, allowing for a more nuanced understanding of age-related differences in allergen sensitization. Second, all patients were evaluated using the ESS patch testing under standardized conditions, and readings were performed at both 48 and 96 h according to the ICDRG criteria. Finally, this study contributes valuable data from a Mediterranean (Anatolian) population, which remains underreported in the context of geriatric ACD and may differ from other world populations in environmental and cultural exposure patterns.

Despite its strengths, this study has several limitations that we should acknowledge. Firstly, as it is a single-center, retrospective study, the findings may be difficult to generalize to other populations or geographic regions. Secondly, the sample size of the old-old group was relatively small. Thirdly, while the ESS patch test panel provides broad coverage of common allergens, it may not include emerging or region-specific allergens, which could lead to certain clinically relevant sensitivities being underdetected. Fourthly, detailed information on cumulative lifetime exposure to allergens, personal care products, and natural remedies (such as propolis) was limited. Finally, this study did not include functional or immunological assessments, such as T-cell profiling or skin barrier measurements. These assessments could have provided insights into the mechanisms underlying the observed age-related differences in patch test reactivity.

Further studies with larger sample sizes are needed to better understand the mechanisms underlying age-related differences in contact allergen sensitization. Integrating factors such as comorbidities, medication use, and cumulative environmental exposure could provide a more comprehensive understanding of ACD in the elderly population. The detection of potential allergens through patch testing is crucial for improving the quality of life of this growing demographic group.

Mandatory Disclosure on Use of Artificial Intelligence

The authors declare that the artificial intelligence-based DeepL application was used solely for language editing and grammatical refinement. All scientific content, interpretations, and conclusions presented in this manuscript were developed exclusively by the authors. Furthermore, all references were manually verified to ensure accuracy and relevance.

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Consent for Publication

The authors consent to the publication of this manuscript.

Author's Contributions

The author designed the study, collected and analyzed data, and wrote the manuscript.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to research, authorship, and/or publication of this article.

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