

Original article

Deodorant and Antiperspirant Use, Awareness of Aluminum Content, and Breast Cancer: An Unmatched Case-Control Study Among Women in Benghazi, Libya

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Abstract

Public concern links aluminium-based antiperspirants to breast cancer, but the epidemiological evidence is inconsistent, and no data exist for Libya. We described deodorant and antiperspirant use and awareness of aluminium content among women in Benghazi and compared women with and without breast cancer. In this unmatched case-control study, 50 women with breast cancer at Benghazi Medical Centre and 150 women without cancer completed a self-administered questionnaire between January and March 2025. We compared groups with Fisher's exact and chi-square tests and estimated crude and age-adjusted odds ratios (ORs) by logistic regression. Awareness was low in both groups: 26.2% of controls and 26.5% of cases read ingredient labels, and 11.7% and 10.0% had noticed aluminium among the ingredients. Cases were older than controls (78.0% versus 32.7% aged 40 years or more). After age adjustment, breast cancer was associated with product use for more than 10 years (OR 5.46, 95% CI 2.41–12.36), hormone replacement therapy (OR 5.88, 95% CI 2.02–17.08), and a family history of breast cancer (OR 3.64, 95% CI 1.56–8.50). Exclusive antiperspirant use (OR 2.22, 95% CI 0.85–5.78), application immediately after hair removal (OR 2.39, 95% CI 0.97–5.90), and razor use (OR 0.65, 95% CI 0.25–1.71) showed no significant association. Few women read labels or knew that their products contained aluminium, which supports consumer education and clearer labelling. The association with long-term use may reflect residual confounding and recall bias. Larger age-matched studies with objective exposure measurement are needed.

Keywords: Breast Cancer, Antiperspirants, Aluminum, Consumer Awareness, Libya.

Introduction

Breast cancer is the most frequently diagnosed cancer and the leading cause of cancer death among women worldwide [1]. Its established risk factors include age, family history, reproductive history, and exogenous hormones. Public concern has also focused on underarm antiperspirants, which contain aluminium salts and are applied daily to skin next to breast tissue. Two biological hypotheses drive this concern. Aluminium has been proposed to interfere with estrogen action and has a genotoxic profile [2,3], and shaving may disrupt the skin barrier and increase absorption [4]. Aluminium has been measured at higher concentrations in the outer than in the inner regions of the breast [5] and has been detected in breast tissue from women with breast cancer [6].

Aluminum content in nipple aspirate fluid has also been compared between healthy women and women with breast cancer [7], whereas a study of malignant lesions and normal breast tissue found no difference [8]. In culture, long-term aluminium exposure increased the migratory and invasive properties of MCF-7 breast cancer cells [9], and aluminium chloride promoted tumorigenesis and metastasis in normal murine mammary epithelial cells [10]. Dermal absorption appears small. Tracer studies with aluminium-26 estimated that about 0.01% of applied aluminium crosses intact skin [11,12]. In vitro absorption was higher through stripped skin [13], and 14 days of daily antiperspirant use did not raise plasma or urinary aluminium in healthy volunteers [14].

Epidemiological studies disagree. A large population-based case-control study in the United States found no association with antiperspirant or deodorant use, including use after shaving [15]. McGrath [4] reported an earlier age at diagnosis among survivors who used these products more often and shaved more often, but that study included no cancer-free comparison group. In Iraq, antiperspirant use was more common among controls than among cases [16], and two Iranian comparative studies found no association [17,18]. By contrast, an Austrian age-matched case-control study linked frequent use beginning before age 30 with higher breast-tissue aluminium and higher risk [19]. The Sister Study cohort assessed usage patterns across beauty, skin, and hair products and reported modest associations with moderate or frequent use of beauty products and frequent use of skincare products among white women, but none with hair products [20].

A systematic review identified only two eligible case-control studies [21], and narrative and regulatory reviews concluded that the evidence does not support a causal link [22–24]. Consumer knowledge also matters. Post-marketing surveillance of cosmetics depends on informed consumers and health professionals [25]. No study has described how women in Libya use these products or whether they know what the products contain. We therefore described deodorant and antiperspirant use and awareness of aluminium content among women in Benghazi and compared women with and without breast cancer, with explicit attention to the age difference between groups.

Methods

Study design and participants

We conducted an unmatched case-control study in Benghazi, Libya. Participants were recruited from January to March 2025. Cases were women with breast cancer identified at the Oncology Department of Benghazi Medical Centre; a consultant oncologist confirmed each diagnosis from clinical records and histopathology reports. Controls were women without a known diagnosis of cancer, recruited from the general population and outpatient clinics of Benghazi during the same period. We excluded from the control group any woman with a previous diagnosis of a malignant disease. We used convenience sampling for both groups: we enrolled the women who were available and agreed to participate during the recruitment period. The sample comprised 50 cases and 150 controls, and its size reflects the number of women recruited, not a prior power calculation. (Figure 1) summarises recruitment.

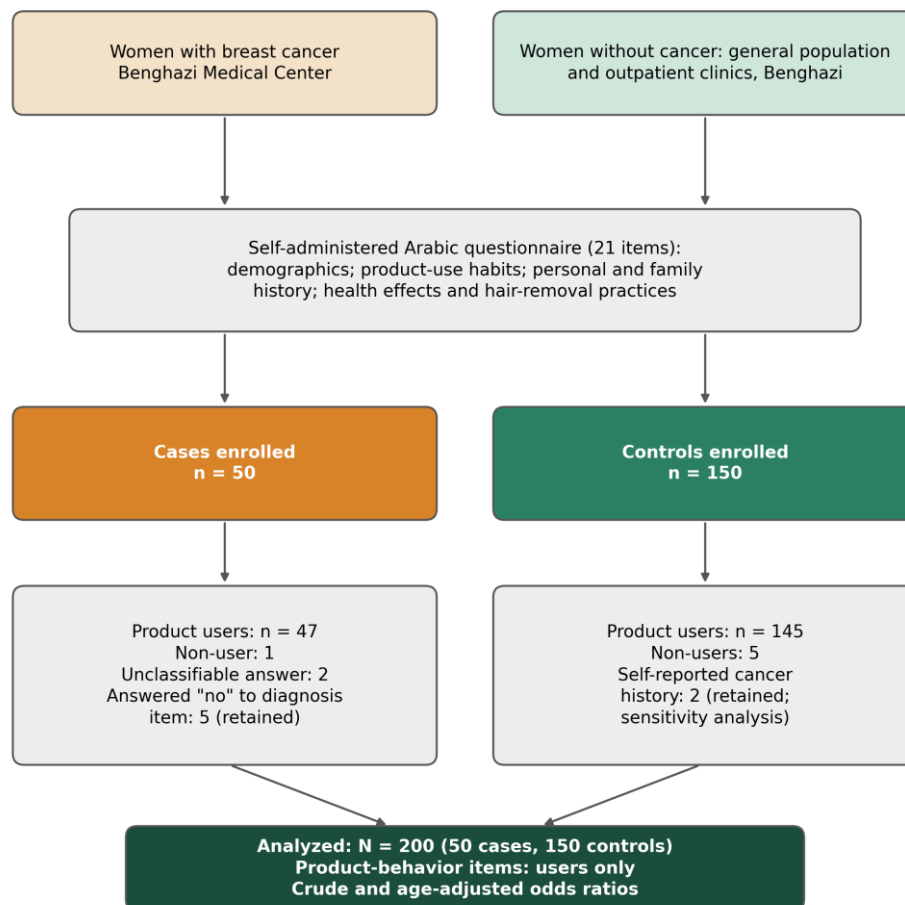


Figure 1. Recruitment of cases and controls and structure of the questionnaire.

Questionnaire

Participants completed a self-administered Arabic questionnaire of 21 items in four sections: general information (age group, marital status, education, occupation); product-use habits (frequency, type, form, duration, reading of ingredient labels, noticing aluminum among ingredients, use of aluminum-free products, selection criteria); personal and family health history (cancer diagnosis, family history of breast cancer, breast self-examination); and health effects and practices (allergic reactions, axillary skin changes, timing of application after hair removal, hair-removal method, hormone replacement therapy, knowledge of aluminum and breast health). Product items offered an “I do not use it” option. Selection criteria, hair-removal method, and type of skin change allowed more than one answer. The instrument is provided as supplementary material. We did not measure aluminium in products or tissue.

Statistical Analysis

We report categorical data as n (%) of women with a valid answer. Denominators vary by item because non-users were excluded from product-behaviour items and a few answers were missing or unclassifiable; each table lists the valid number of controls and cases. We compared cases and controls with Fisher's exact test for 2 × 2 tables and Pearson's chi-square test for larger tables, using a Monte Carlo exact p-value (100,000 permutations) when any expected count was below 5. Multiple-answer items were analysed option by option. For six exposures of main interest, we estimated crude and age-adjusted odds ratios (ORs) with 95% Wald confidence intervals (CIs) by logistic regression; the adjusted model included age as a continuous (scale) variable to provide a more rigorous adjustment for confounding, thereby avoiding the limitations

of broad, open-ended age categories. Because the questionnaire recorded age in five groups (<20, 20–29, 30–39, 40–49, and ≥50 years), the scale variable was the group score, entered as a single linear term with one unit per 10-year group. With 50 cases, we did not adjust for further covariates. In a sensitivity analysis, we excluded two controls who reported a personal history of cancer. We did not correct for multiple comparisons and regard all results as exploratory. Tests were two-sided with $\alpha = 0.05$. Given the final sample size of 50 cases and 150 controls, a post hoc power calculation was performed that did not use the observed effect sizes. With $\alpha = 0.05$ and 80% power, the study could detect an odds ratio of 2.7 or higher for product use for more than 10 years, 3.2 or higher for family history, and 4.7 or higher for hormone replacement therapy, according to the prevalence of each exposure among controls; the corresponding values for the other three exposures were 2.8 to 3.1. Associations smaller than these would probably not be detected. We analysed the data in IBM SPSS Statistics version 21 and independently recomputed all reported statistics in Python 3 with SciPy and statsmodels.

Ethical considerations

The study followed the Declaration of Helsinki. All participants provided informed consent after receiving information about the study objectives, procedures, voluntary nature of participation, and confidentiality measures. Participants were informed of their right to withdraw at any time without consequences. The questionnaires were completed anonymously, and no personal identifiers were recorded.

Results

Participants

The two groups differed in age, marital status, and occupation (Table 1; Figure 2). Of the cases, 78.0% were aged 40 years or more, compared with 32.7% of the controls, and no case was younger than 20 years (controls: 22.7%). Cases were more often married (75.5% versus 42.7%), and none were students (controls: 39.3%). Educational level did not differ ($p = 0.72$). Two controls reported a personal history of cancer, and five cases answered “no” to the diagnosis question; we analysed all women according to their recruitment group.

Table 1. Demographic characteristics of cases and controls.

Variable	Category	Control s n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Age group	<20 years	34 (22.7)	0 (0.0)	150/50	<0.001
	20–29 years	39 (26.0)	2 (4.0)		
	30–39 years	28 (18.7)	9 (18.0)		
	40–49 years	27 (18.0)	18 (36.0)		
	≥50 years	22 (14.7)	21 (42.0)		
Marital status	Single	75 (50.0)	6 (12.2)	150/49	<0.001
	Married	64 (42.7)	37 (75.5)		
	Divorced	5 (3.3)	3 (6.1)		
	Widowed	6 (4.0)	3 (6.1)		
Occupation	Student	59 (39.3)	0 (0.0)	150/50	<0.001
	Employed	53 (35.3)	29 (58.0)		
	Unemployed/housewife	35 (23.3)	19 (38.0)		
	Other	3 (2.0)	2 (4.0)		
Educational level	Less than high school	37 (24.7)	14 (28.6)	150/49	0.72
	High school	23 (15.3)	10 (20.4)		
	University	80 (53.3)	22 (44.9)		
	Postgraduate	10 (6.7)	3 (6.1)		

Percentages exclude missing answers (cases: marital status 1, education 1). p-values: chi-square test (age); Monte Carlo exact chi-square test (other variables).

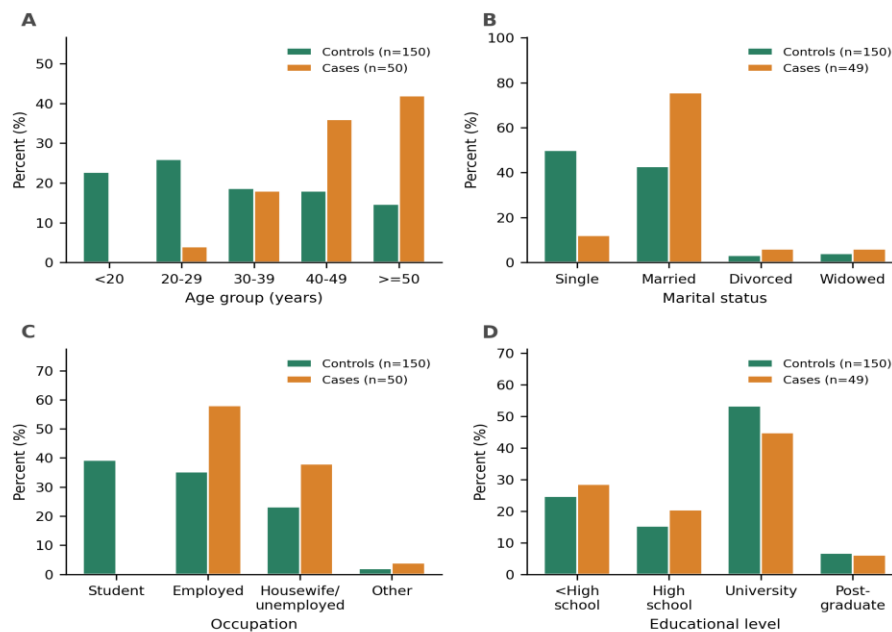


Figure 2. Demographic characteristics of cases and controls. (A) Age group. (B) Marital status. (C) Occupation. (D) Educational level. Bars show the percentage of each group.

Product use

Almost all women used deodorants or antiperspirants (145 of 150 controls and 47 of 50 cases with a classifiable answer). Application frequency and product form did not differ between groups (Table 2; Figure 3). Product type differed ($p < 0.001$): more cases used antiperspirant only (29.8% versus 13.1%), and fewer used both product types (4.3% versus 26.2%). Most cases had used these products for more than 10 years (75.0% versus 23.6% of controls; $p < 0.001$).

Table 2. Deodorant and antiperspirant use among women with a valid answer.

Variable	Category	Controls n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Applications per day	Once daily	102 (70.3)	33 (70.2)	145/47	0.87
	Twice daily	28 (19.3)	8 (17.0)		
	Several times daily	15 (10.3)	6 (12.8)		
Product type	Deodorant only	88 (60.7)	31 (66.0)	145/47	<0.001
	Antiperspirant only	19 (13.1)	14 (29.8)		
	Both	38 (26.2)	2 (4.3)		
Product form	Cream	71 (49.3)	22 (47.8)	144/46	0.79
	Spray	34 (23.6)	12 (26.1)		
	Roll-on	26 (18.1)	8 (17.4)		
	Solid/stick	8 (5.6)	1 (2.2)		
	More than one form	5 (3.5)	3 (6.5)		
Duration of use	<5 years	55 (38.2)	3 (6.2)	144/48	<0.001
	5–10 years	55 (38.2)	9 (18.8)		
	>10 years	34 (23.6)	36 (75.0)		

Denominators exclude non-users and unclassifiable or missing answers. p-values: chi-square test, or Monte Carlo exact chi-square test for product form.

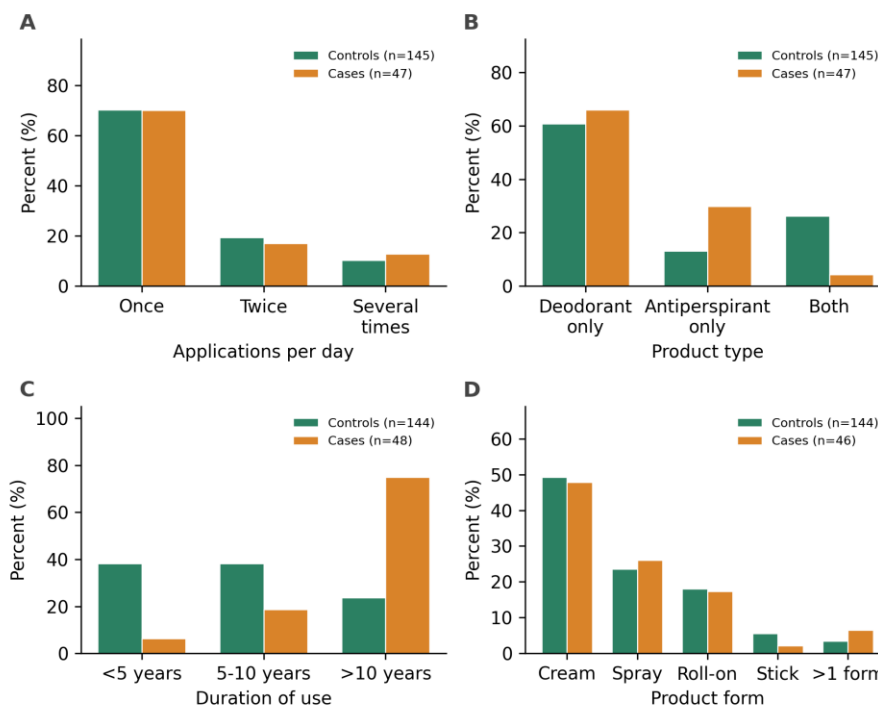


Figure 3. Product use among women with a valid answer. (A) Applications per day. (B) Product type. (C) Duration of use. (D) Product form.

Awareness of Ingredients

About one quarter of the women in each group read ingredient labels (26.2% of controls and 26.5% of cases), and about one in ten had noticed aluminium/aluminum among the ingredients (11.7% and 10.0%; Table 3; Figure 4). Knowledge that aluminium may affect breast health was similar (27.3% and 30.0%). More cases than controls reported using aluminium-free products (36.0% versus 22.6%; $p = 0.092$).

Table 3. Label reading and awareness of aluminium.

Variable	Category	Controls n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Reads ingredient labels	Yes	38 (26.2)	13 (26.5)	145/49	>0.99
	No	107 (73.8)	36 (73.5)		
Noticed aluminum among ingredients	Yes	17 (11.7)	5 (10.0)	145/50	>0.99
	No	128 (88.3)	45 (90.0)		
Uses aluminum-free products	Yes	33 (22.6)	18 (36.0)	146/50	0.092
	No	113 (77.4)	32 (64.0)		
Knows aluminum may affect breast health	Yes	41 (27.3)	15 (30.0)	150/50	0.72
	No	109 (72.7)	35 (70.0)		

Fisher's exact test. Percentages use the valid number of answers shown in the fifth column. The knowledge item was asked of all participants.

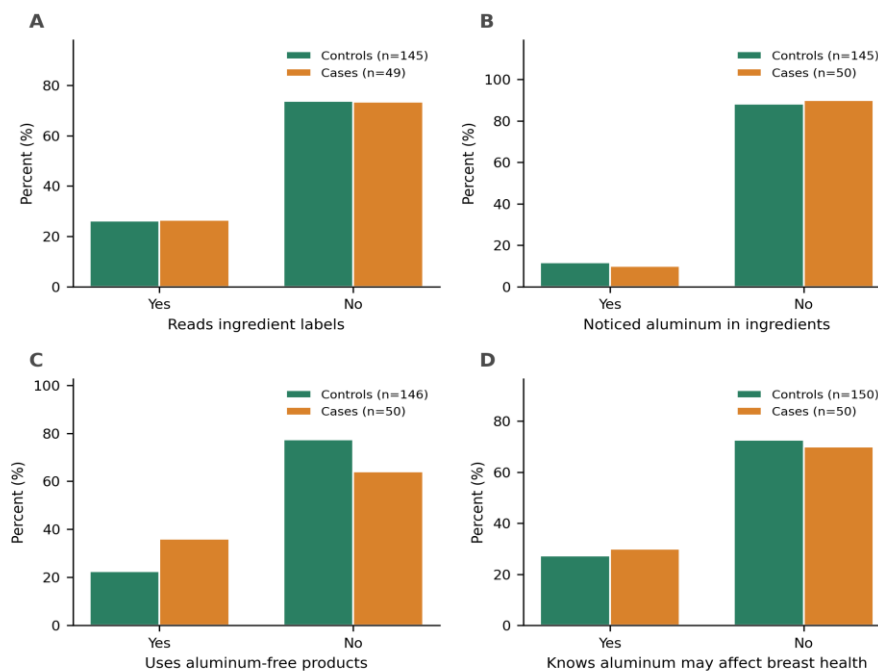


Figure 4. Awareness of ingredients. (A) Reading of ingredient labels. (B) Noticing aluminium/aluminium among ingredients. (C) Use of aluminium-free products. (D) Knowledge that aluminium may affect breast health.

Product-Selection Criteria

Quality was the criterion most often cited by controls (56.6%; cases 42.6%, $p = 0.13$). Cases cited scent (48.9% versus 25.5%; $p = 0.004$) and brand (19.1% versus 6.9%; $p = 0.023$) more often than controls (Table 4). Few women in either group chose a product on medical advice (9.7% of controls and 2.1% of cases; $p = 0.12$).

Table 4. Product-selection criteria among women with a valid answer (more than one answer allowed).

Variable	Category	Controls n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Selection criterion*	Quality	82 (56.6)	20 (42.6)	145/47	0.13
	Scent	37 (25.5)	23 (48.9)		0.004
	Brand	10 (6.9)	9 (19.1)		0.023
	Price	7 (4.8)	4 (8.5)		0.47
	Medical recommendation	14 (9.7)	1 (2.1)		0.12

*Percentages are of respondents (controls $n = 145$; cases $n = 47$) and may sum to more than 100%. Fisher's exact test for each criterion.

Health History

A family history of breast cancer (40.0% versus 11.5%) and hormone replacement therapy (28.0% versus 4.7%) were more common among cases (both $p < 0.001$; Table 5; Figure 5). Regular breast self-examination was reported by 34.7% of cases and 1.3% of controls ($p < 0.001$); this difference most likely reflects screening behaviour after diagnosis.

Table 5. Family history, breast self-examination, and hormone replacement therapy.

Variable	Category	Controls n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Family history of breast cancer	Yes	17 (11.5)	20 (40.0)	148/50	<0.001
	No	131 (88.5)	30 (60.0)		
Breast self-examination	Regular	2 (1.3)	17 (34.7)	150/49	<0.001
	Irregular	38 (25.3)	9 (18.4)		
	None	110 (73.3)	23 (46.9)		
Hormone replacement therapy	Yes	7 (4.7)	14 (28.0)	150/50	<0.001
	No	143 (95.3)	36 (72.0)		

Missing answers: family history, 2 controls (answer "unknown"); self-examination, 1 case. p-values: Fisher's exact test; Monte Carlo exact chi-square test for self-examination.

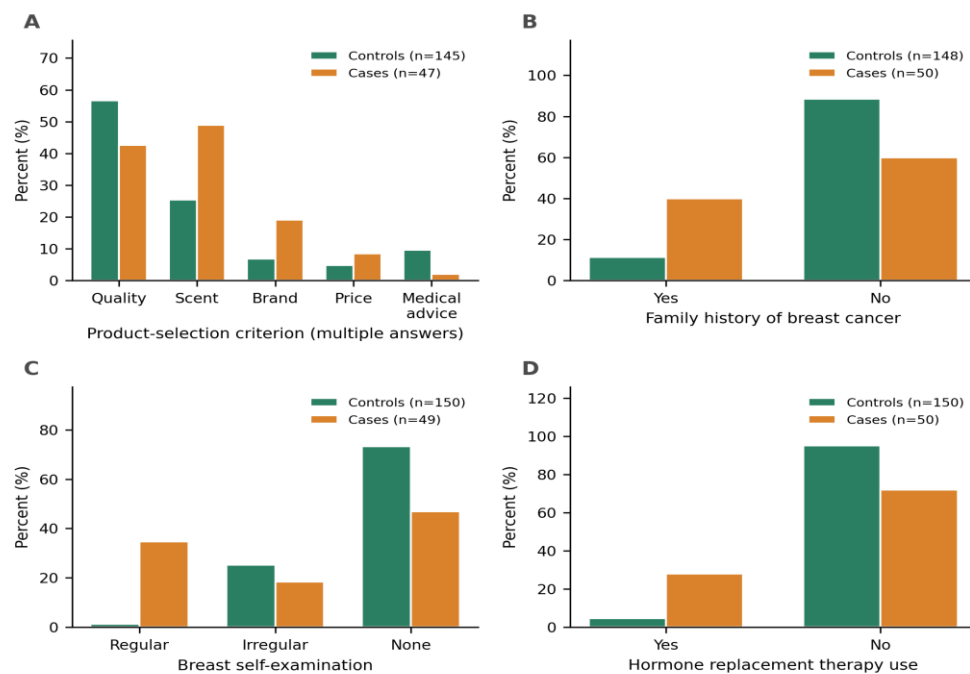


Figure 5. Selection criteria and health history. (A) Product-selection criteria (more than one answer allowed). (B) Family history of breast cancer. (C) Breast self-examination. (D) Hormone replacement therapy.

Hair Removal and Skin Effects

Sugaring or waxing was the main hair-removal method in both groups (82.0% of controls and 79.2% of cases), and razor use was similar (18.7% and 16.7%; $p = 0.83$; Table 6; Figure 6). More cases than controls named an unspecified other method (12.5% versus 0.7%; $p < 0.001$). Application immediately after hair removal was more frequent among cases (29.8% versus 15.9%), but the difference did not reach significance ($p = 0.054$). Allergic reactions, axillary skin changes, and each specific skin symptom were reported at similar rates in both groups.

Table 6. Hair removal, timing of application, and skin effects.

Variable	Category	Controls n (%)	Cases n (%)	Valid n (controls/cases)	p-value
Hair-removal method*	Sugaring/waxing	123 (82.0)	38 (79.2)	150/48	0.67
	Razor	28 (18.7)	8 (16.7)		0.83
	Electronic device	3 (2.0)	0 (0.0)		>0.99
	Depilatory cream	2 (1.3)	1 (2.1)		0.57
	Other	1 (0.7)	6 (12.5)		<0.001
Application after hair removal	Immediately after	23 (15.9)	14 (29.8)	145/47	0.054
	After 24 hours	122 (84.1)	33 (70.2)		
Allergic reaction or irritation	Yes	37 (25.3)	16 (33.3)	146/48	0.35
	No	109 (74.7)	32 (66.7)		
Any axillary skin change	Any change	49 (33.8)	16 (33.3)	145/48	>0.99
	No change	96 (66.2)	32 (66.7)		
Type of skin change*	Redness	30 (20.7)	12 (25.0)	145/48	0.55
	Irritation	14 (9.7)	9 (18.8)		0.12
	Swelling	5 (3.4)	2 (4.2)		>0.99
	Sores	2 (1.4)	0 (0.0)		>0.99

*More than one answer allowed; percentages are of respondents and p-values are Fisher's exact tests for each option. Other rows: Fisher's exact test among women with a valid answer. "Other" hair-removal methods were written in without further detail.

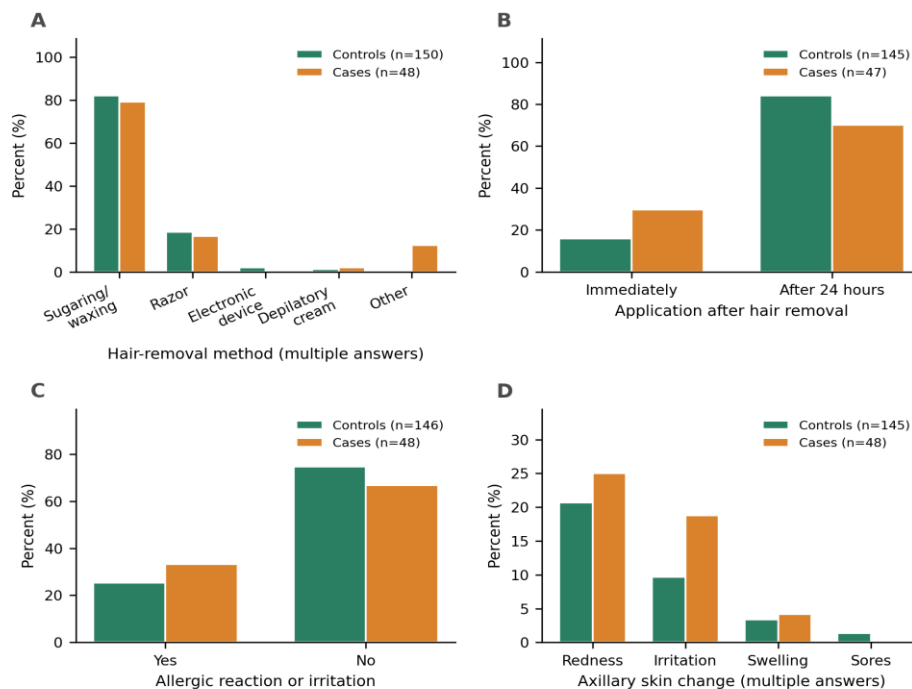


Figure 6. Hair removal and skin effects. (A) Hair-removal method (more than one answer allowed). (B) Timing of application after hair removal. (C) Allergic reaction or irritation. (D) Type of axillary skin change (more than one answer allowed).

Crude and Age-Adjusted Odds Ratios

Age adjustment attenuated the three strongest associations, all of which remained significant: product use for more than 10 years (OR 9.71 to 5.46), hormone replacement therapy (7.94 to 5.88), and family history (5.14 to 3.64) (Table 7; Figure 7). Exclusive antiperspirant use, application immediately after hair removal, and razor use were not significantly associated with breast cancer after adjustment. Excluding the two controls who reported a personal history of cancer changed no adjusted OR by more than 0.1.

Table 7. Crude and age-adjusted odds ratios for breast cancer.

Exposure (reference)	n (controls/cases)	Crude OR (95% CI)	p- value	Age-adjusted OR (95% CI)	p- value
Duration >10 years (vs ≤10 years)	144/48	9.71 (4.55–20.71)	<0.001	5.46 (2.41–12.36)	<0.001
Hormone replacement therapy (yes vs no)	150/50	7.94 (2.99–21.13)	<0.001	5.88 (2.02–17.08)	0.001
Family history (yes vs no)	148/50	5.14 (2.41–10.97)	<0.001	3.64 (1.56–8.50)	0.003
Antiperspirant only (vs deodorant only)	107/45	2.09 (0.94–4.67)	0.072	2.22 (0.85–5.78)	0.103
Immediate application after hair removal	145/47	2.25 (1.04–4.85)	0.038	2.39 (0.97–5.90)	0.059
Razor use (yes vs no)	150/48	0.87 (0.37–2.07)	0.75	0.65 (0.25–1.71)	0.38

Logistic regression with 95% Wald CIs and Wald p-values; the adjusted model includes age as a scale variable (age-group score, one unit per 10-year group). Product-behaviour exposures are restricted to women with a valid answer. Wald p-values can differ slightly from Fisher's exact p-values in (Tables 2 to 6).

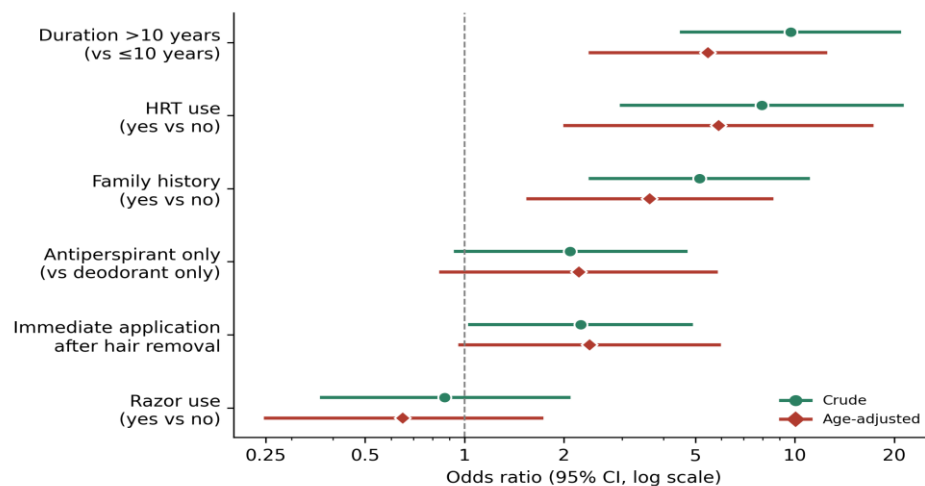


Figure 7. Crude (circles) and age-adjusted (diamonds) odds ratios with 95% confidence intervals for the exposures in Table 7. The x-axis is logarithmic; the dashed line marks OR = 1.

Discussion

This first study of deodorant and antiperspirant use among Libyan women produced two main findings. Few women in either group read ingredient labels or knew that their products contained aluminium. After adjustment for age, breast cancer was associated with long-term product use, hormone replacement therapy, and family history, whereas the exposures most specific to the aluminium hypothesis showed no significant association. The awareness findings are the most robust results of the study. They describe both groups equally, so the age difference between cases and controls does not distort them. Only one woman in four read ingredient labels, one in ten had noticed aluminium/aluminium, and choices rested on quality, scent, and brand rather than on health information. More women reported using aluminium-free products (22.6% of controls) than reported noticing aluminium in any product (11.7%), which suggests that some women judged products by marketing claims rather than by the label. Cases cited scent and brand more often and reported aluminium-free products more often; these differences may reflect changes made after diagnosis. Consumer education and clear labelling of aluminium content would address this gap regardless of how the causal question is resolved [25]. Family history and hormone replacement therapy are established risk factors, and their associations here support the validity of case ascertainment.

The association with product use for more than 10 years deserves more caution. Age determines cumulative years of use, and adjustment for age as a scale variable assumes a linear age effect on the log odds and, because age was recorded only in groups, cannot remove all confounding by age. Women with cancer may also recall longer use when they search for a cause. The duration item combined deodorants and antiperspirants, and the questionnaire did not record age at first use, so the association cannot be read as an effect of aluminium. The exposures closest to the aluminium hypothesis showed no significant association: exclusive antiperspirant use, application immediately after hair removal, and razor use. This pattern agrees with the null results of Mirick et al. [15], Fakri et al. [16], and the Iranian studies [17,18], and with reviews that found no convincing evidence of a causal link [21,23,24]. The point estimates for exclusive antiperspirant use and immediate application were above 2 with wide intervals, so this small study cannot exclude a modest effect of the kind reported by McGrath [4] and Linhart et al. [19]. The low dermal absorption measured in human tracer studies argues against a large effect [11,12,14]. Strengths include the inclusion of histologically confirmed cases, anonymous self-completed questionnaires, and exact tests suited to small cells.

The study has several limitations. The controls were younger than the cases, and age was recorded only in groups, so residual confounding by age is possible. Furthermore, the reliance on convenience sampling without an a priori power calculation increases the risk of selection bias, potentially limiting the generalizability of our results to the broader population of Benghazi. The relatively small sample size also increases the width of our confidence intervals. Future studies should utilize population-based sampling with pre-calculated statistical power. Exposure was self-reported and retrospective, so recall bias is possible. The questionnaire did not distinguish products with and without aluminium/aluminium, and we did not measure aluminium/aluminium in products or tissue. Two controls reported a personal history of cancer and five cases answered “no” to the diagnosis item; we retained them and tested the effect in a sensitivity analysis. We tested many comparisons without correction, so isolated significant results should be read as hypothesis-generating.

Conclusion

Women in Benghazi, with and without breast cancer, seldom read ingredient labels or knew that their products contained aluminium. Long-term product use remained associated with breast cancer after age adjustment, but residual confounding and recall bias may explain this result, and exposures specific to the aluminium/aluminium hypothesis showed no

significant association. The findings support consumer education and clearer labelling and call for larger, age-matched studies with objective measurement of exposure.

Recommendations

Educating consumers in Libya about the composition of personal care products and encouraging them to read ingredient labels is essential for informed purchasing decisions. In addition, regulatory measures should require clear labeling of aluminium content on underarm products sold in Libya. Furthermore, age-matched studies with adequate statistical power for multivariable analysis and objective measurement of aluminium exposure should be conducted before making product-specific risk claims.

Authors' Contributions

Abdelmuhsen M. Abusneina wrote the original manuscript and performed the analysis. Ali A. Almabsoot carried out the statistical analysis in SPSS. Zainab A. Alhursh designed the questionnaire, conducted the data review, and edited the manuscript. Abdelnaser O. Busba reviewed and edited the manuscript. All authors read and approved the final version.

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Conflicts of Interest

Zainab A. Alhursh, Abdelmuhsen M. Abusneina, Ali A. Almabsoot, and Abdelnaser O. Busba each declare no conflicts of interest.

Data Availability

The anonymised dataset is available from the corresponding author on reasonable request.

References

- Bray F, Laversanne M, Sung H, Ferlay J, Siegel RL, Soerjomataram I, et al. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin.* 2024;74(3):229-263. doi:10.3322/caac.21834
- Darbre PD. Aluminium, antiperspirants and breast cancer. *J Inorg Biochem.* 2005;99(9):1912-1919. doi:10.1016/j.jinorgbio.2005.06.001
- Darbre PD. Underarm antiperspirants/deodorants and breast cancer. *Breast Cancer Res.* 2009;11(Suppl 3):S5. doi:10.1186/bcr2424
- McGrath KG. An earlier age of breast cancer diagnosis related to more frequent use of antiperspirants/deodorants and underarm shaving. *Eur J Cancer Prev.* 2003;12(6):479-485. doi:10.1097/00008469-200312000-00006
- Exley C, Charles LM, Barr L, Martin C, Polwart A, Darbre PD. Aluminium in human breast tissue. *J Inorg Biochem.* 2007;101(9):1344-1346. doi:10.1016/j.jinorgbio.2007.06.005
- House E, Polwart A, Darbre P, Barr L, Metaxas G, Exley C. The aluminium content of breast tissue taken from women with breast cancer. *J Trace Elem Med Biol.* 2013;27(4):257-266. doi:10.1016/j.jtemb.2013.05.002
- Mannello F, Tonti GA, Medda V, Simone P, Darbre PD. Analysis of aluminium content and iron homeostasis in nipple aspirate fluids from healthy women and breast cancer-affected patients. *J Appl Toxicol.* 2011;31(3):262-269. doi:10.1002/jat.1641
- Rodrigues-Peres RM, Cadore S, Febraro S, Heinrich JK, Serra KP, Derchain SF, et al. Aluminum concentrations in central and peripheral areas of malignant breast lesions do not differ from those in normal breast tissues. *BMC Cancer.* 2013;13:104. doi:10.1186/1471-2407-13-104
- Darbre PD, Bakir A, Isakova E. Effect of aluminium on migratory and invasive properties of MCF-7 human breast cancer cells in culture. *J Inorg Biochem.* 2013;128:245-249. doi:10.1016/j.jinorgbio.2013.07.004
- Mandriota SJ, Tenan M, Ferrari P, Sappino AP. Aluminium chloride promotes tumorigenesis and metastasis in normal murine mammary gland epithelial cells. *Int J Cancer.* 2016;139(12):2781-2790. doi:10.1002/ijc.30393
- Flarend R, Bin T, Elmore D, Hem SL. A preliminary study of the dermal absorption of aluminium from antiperspirants using aluminium-26. *Food Chem Toxicol.* 2001;39(2):163-168. doi:10.1016/S0278-6915(00)00118-6
- de Ligt R, van Duijn E, Grossouw D, Bosgra S, Burggraaf J, Windhorst A, et al. Assessment of dermal absorption of aluminum from a representative antiperspirant formulation using a ²⁶Al microtracer approach. *Clin Transl Sci.* 2018;11(6):573-581. doi:10.1111/cts.12579
- Pineau A, Guillard O, Favreau F, Marraud A, Fauconneau B. In vitro study of percutaneous absorption of aluminum from antiperspirants through human skin in the Franz diffusion cell. *J Inorg Biochem.* 2012;110:21-26. doi:10.1016/j.jinorgbio.2012.02.013
- Letzel M, Drexler H, Göen T, Hiller J. Impact of daily antiperspirant use on the systemic aluminum exposure: an experimental intervention study. *Skin Pharmacol Physiol.* 2020;33(1):1-8. doi:10.1159/000502239

15. Mirick DK, Davis S, Thomas DB. Antiperspirant use and the risk of breast cancer. *J Natl Cancer Inst.* 2002;94(20):1578-1580. doi:10.1093/jnci/94.20.1578
16. Fakri S, Al-Azzawi A, Al-Tawil N. Antiperspirant use as a risk factor for breast cancer in Iraq. *East Mediterr Health J.* 2006;12(3-4):478-482.
17. Peyman A, Vaghar MI. Relationship between the use of antiperspirants containing aluminum with breast cancer in patients referred to selected hospitals of Tehran University of Medical Sciences in 2013. *Pak J Med Health Sci.* 2020;14(2):1345-1349.
18. Mousavi M, Vaghar MI. The relationship between use of aluminum-containing anti-perspirant and hair color with breast cancer. *J Family Med Prim Care.* 2021;10(1):182-186. doi:10.4103/jfmpc.jfmpc_1219_19
19. Linhart C, Talasz H, Morandi EM, Exley C, Lindner HH, Taucher S, et al. Use of underarm cosmetic products in relation to risk of breast cancer: a case-control study. *EBioMedicine.* 2017;21:79-85. doi:10.1016/j.ebiom.2017.06.005
20. Taylor KW, Troester MA, Herring AH, Engel LS, Nichols HB, Sandler DP, et al. Associations between personal care product use patterns and breast cancer risk among white and black women in the Sister Study. *Environ Health Perspect.* 2018;126(2):027011. doi:10.1289/EHP1480
21. Allam MF. Breast cancer and deodorants/antiperspirants: a systematic review. *Cent Eur J Public Health.* 2016;24(3):245-247. doi:10.21101/cejph.a4475
22. Namer M, Luporsi E, Gligorov J, Lokiec F, Spielmann M. [The use of deodorants/antiperspirants does not constitute a risk factor for breast cancer]. *Bull Cancer.* 2008;95(9):871-880. French. doi:10.1684/bdc.2008.0679
23. Roth N, FitzGerald R. Aluminum salts in antiperspirants and breast cancer risk. SCAHT report for the Swiss Federal Food Safety and Veterinary Office. Basel: Swiss Centre for Applied Human Toxicology; 2017 Sep 20.
24. Sanajou S, Şahin G, Baydar T. Aluminium in cosmetics and personal care products. *J Appl Toxicol.* 2021;41(11):1704-1718. doi:10.1002/jat.4228
25. Altıokka İ, Üner M. Safety in cosmetics and cosmetovigilance, current regulations in Türkiye. *Turk J Pharm Sci.* 2022;19(5):610-617. doi:10.4274/tjps.galenos.2021.40697