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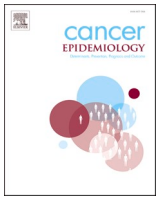

# Prevalence, incidence and trends of keratinocyte carcinoma in Denmark 2007–2021: A population-based register study

Anne Sofie Krogh Holdam [a,b,*], Vibeke Koudahl [c], Erik Frostberg [d], Karina Rønlund [e], Hans Bjarke Rahr [b,d]

[a] Department of Surgery, Plastic Surgery division, University Hospital of Southern Denmark, Vejle Hospital, Denmark
[b] Institute of Regional Health Research, University of Southern Denmark, Denmark
[c] Department of Plastic Surgery, Odense University Hospital, Denmark
[d] Department of Surgery, University Hospital of Southern Denmark, Vejle Hospital, Denmark
[e] Department of Clinical Genetics, University Hospital of Southern Denmark, Vejle Hospital, Denmark

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ABSTRACT

*Introduction:* The incidence of keratinocyte carcinoma (KC), i.e., basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), is increasing worldwide, placing a significant burden on healthcare resources. This is especially the case for tumors requiring surgical intervention. It remains unclear whether this increase is a result of the population aging or a genuine increase in risk of skin cancer. Understanding age-adjusted incidence trends of KC is crucial for improving future management of the disease. We studied these trends in a large nationwide cohort, focusing on large, invasive, and surgically challenging tumors.

*Methods:* Information on all incident cases of BCC and SCC in Denmark was extracted from population-based databases in the calendar years 2007–2021. Age-adjusted incidence rates were calculated, standardized to the 2013 European Standard Population. Average annual percentage changes were estimated using Joinpoint regression models. Incidence trends for larger, more invasive tumors (tumor (T) category of ≥T2), and of those in the head and neck area, were elucidated with descriptive statistics.

*Results:* We found 183,338 patients with a first-time incidence of BCC and 42,233 patients with a first-time incidence of SCC in the period 2007–2021. The incidence rate, adjusted for age, increased from 252 to 338 per 100,000 for BCC and from 49 to 104 per 100,000 for SCC. For SCC, the increase was particularly pronounced in the last two years of the study period. Tumors ≥T2, and those in the head and neck area, increased markedly.

*Conclusion:* KC is the most common type of cancer worldwide, and the age-adjusted incidence rates of BCC and SCC increased significantly from 2007 to 2021, as did tumors with a higher T category and those located in anatomically sensitive areas. Since the primary treatment for many of these tumors is surgical, this raises concern about the strain on future healthcare resources.

## 1. Introduction

Keratinocyte carcinoma (KC), comprising the subtypes basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), is the most common malignancy worldwide, with steadily increasing incidence rates [1]. While the impact on healthcare costs is undeniable [2], the true extent of the burden is not well understood due to sparse epidemiological data, particularly on tumor (T) category and anatomical location.

The highest incidence rates of KC are reported in Australia, New Zealand, and Northern Europe [3–6]. Sun exposure is generally accepted as the main risk factor for developing KC, with early, intermittent overexposure to the sun being the most important cause of BCC, [7] while cumulative sun exposure is the main factor for developing SCC [8]. Despite being among the most frequently diagnosed malignancies globally, underreporting and incomplete registration of KC may lead to a skewed perception of its true prevalence. In contrast to most other countries, Denmark has a history of nationwide, extensive registration of KC. The most recent comprehensive analysis, however, only includes data up to 2007, and an updated assessment is necessary [9]. The

* Correspondence to: Department of Surgery, Plastic Surgery Division, University Hospital of Southern Denmark, Beriderbakken 4, Vejle 7100, Denmark.
*E-mail address:* anne.sofie.krogh.holdam@rsyd.dk (A.S.K. Holdam).

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majority of patients diagnosed with KC are elderly, and the population is aging significantly [10]. It remains to be examined whether the rise in KC cases is due to the growing elderly population or persists after adjusting for age.

KC, especially BCC, usually has a good prognosis but can cause morbidity due to local invasion [11]. Treatment options vary by tumor type, size, and location. Smaller, superficial BCCs can be treated non-surgically while larger and more invasive BCCs, especially located in the head and neck area, often require surgery [12]. SCC has a higher risk of recurrence and is primarily treated surgically with wider excision margins [13,14]. Most epidemiological data on KC lack details on T category and anatomical location, which are important factors for understanding the burden on surgical services and ensuring proper resource allocation.

### 1.1. Aim

This study aimed to examine the recent incidence rates of keratinocyte carcinoma adjusted for age and gender, and to provide an in-depth description of time trends in tumor (T) category at the time of diagnosis as well as in anatomical location.

## 2. Materials and methods

### 2.1. Study design

This is a nationwide population-based registry study.

### 2.2. Study population

All patients over the age of 20 years with a first-time incidence of KC in Denmark were included from The Danish Cancer Registry for the period January 1, 2007, to December 31, 2021.

### 2.3. Registries

The Danish Cancer Registry [15] has recorded first incident non-melanoma skin cancer (NMSC), diagnosed in private practices, dermatology clinics, and Danish hospitals since 1978. The registry collects and maintains detailed information on morphology, T category, and topography. For this study, we included only BCC tumors (morphology code M-809 × 3) and SCC tumors (morphology codes M-807 × 3 and M-80833/M-80843). The T category was divided into T1 and ≥T2.

Most tumors were included in The Danish Registry of Pathology [16], which provided anatomical location information when it was missing from The Danish Cancer Registry. However, for 35,846 BCC patients (20 %) and 3344 SCC patients (8 %), no information was available in The Danish Registry of Pathology. In these cases, we relied on clinical data regarding size and anatomical location, recorded by their primary physician in the Cancer Registry. Notably, 58 % of SCC cases absent from the Pathology Registry occurred in 2020 and 2021, likely due to the COVID-19 pandemic.

Statistics Denmark provided information on the Danish population during the study period, grouped into 10-year age groups from 20 to 80 + .

Data were merged using the Danish unique personal identification number (PIN) as an identifier.

### 2.4. Statistical analysis

To describe and assess trends in the incidence of KC over the study period, age- and sex-specific incidence rates were estimated. We used the first incident KC diagnosis as the numerator and the actual Danish population as the denominator, then applied direct standardization to the 2013 European standard population [17].

To estimate trends over time, incidence rates were first calculated for each year in the study period, and the average annual percentage change (AAPC) was then analyzed using the Joinpoint Regression Program [18], by sex and age over the entire 15-year period. In addition, we utilized the program to investigate trends within time segments in the study period, to calculate the annual percentage change (APC). In a log-linear model, the APC is the constant percent change in rates per year, and can be positive with increasing incidence or negative with decreasing incidence. If the trend is linear, the AAPC and APC will be the same. The results are reported as trend graphs and percentage changes with 95 % confidence intervals (CIs). The Weighted Bayesian Information Criterion was used to select the optimal model. The chosen level of significance was $P < 0.05$. Descriptive statistics depict the change with time of T classifcation and anatomical location of the tumors.

Due to the inherent differences in the two types of KC, we analyzed information on incidence rates, T category and anatomical location separately for BCC and SCC.

## 3. Ethics

The project was approved by the National Danish Health Authority and Statistics Denmark. All data linkage was performed in accordance with the Danish Act on Processing Personal Data. Data management was approved by the Danish Data Protection Agency through the local authorities (21/44778). As this is a registry study with no contact with individual patients, no other approvals were required under Danish law.

## 4. Results

From 2007 to 2021, we found 222,311 patients with an ICD-10 code of C44. Out of these, 183,338 patients were diagnosed with a first-time incidence of BCC, and 42,233 patients were diagnosed with a first-time incidence of SCC, and were included in further analyses (Fig. 1). Of these, 11,985 patients had both a first-time incidence of BCC and SCC. The annual number of first incident BCC cases increased from 9583 in 2007–15,698 in 2021 while the annual number of first incident SCC cases increased from 1751 in 2007–4866 in 2021. The median age of diagnosis increased from 66 to 68 years for BCC and from 75 to 77 years for SCC. The male to female ratio was 1:1.1 for BCC and 1:0.8 for SCC. For details on basic characteristics of the patients, see Table 1.

### 4.1. Incidence rates

#### 4.1.1. Age-adjusted incidence rates

Throughout the study period, the overall age-adjusted incidence rates of BCC increased from 265 to 347 per 100,000 for men and 247–334 per 100,000 for women. The rates are age-standardised with the European Standard Population 2013. From 2010 to 2014, a decrease in incidence rate was observed for men, followed by an increase from 2014 onwards. For women, the increase was steady through the entire period (Fig. 2a and Table 2a). The calculated AAPC from 2007 to 2021 were 1.8 % for both men and women (95 % CI for men: 1.5–2.2 and 95 % CI for women: 1.1–2.4).

For SCC, the age-adjusted incidence rates increased from 67 to 133 per 100,000 for men and 35–83 per 100,000 for women (Fig. 2d). The AAPC were 4.6 % (95 % CI: 3.7–5.8) for men and 6.1 % (95 % CI: 5.2–7.3) for women. For both sexes, the increase was especially remarkable in the last two years of the study period (2019–2021). The APC for these years were 12.2 % (95 % CI: 5.2–16.5) for men and 15.3 % (95 % CI: 6.5–20.3) for women (Table 2b).

#### 4.1.2. Age-specific incidence rates

The incidence rates of BCC were higher in the younger age groups (20−59) for women than for men and nearly identical in the age group 60–69 (Figs. 2c and 2d). Conversely, in the older age groups (70 +), rates were higher for men (Fig. 2b). The peak incidence rate was

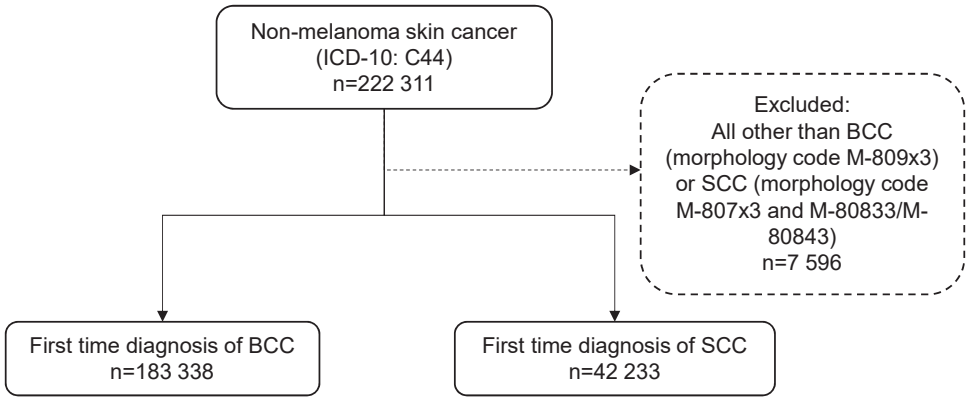


**Fig. 1.** Flowchart on inclusion and exclusion criteria.

**Table 1**
Basic characteristics of patients with a first time diagnosis of basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) 2007–2021.

| | BCC (n = 183,338) | SCC (n = 42,233) |
|---|---|---|
| **Age, median(IQR)** | 68 (58–77) | 77 (70–84) |
| **Sex, n (%)** | | |
| Male | 87,592 (48) | 24, 006 (57) |
| Female | 95,746 (52) | 18, 227 (43) |
| **Age at diagnosis, n (%)** | | |
| 20–29 | 906 (<1) | 33 (<1) |
| 30–39 | 4 982 (3) | 153 (<1) |
| 40–49 | 16,558 (9) | 719 (2) |
| 50–59 | 28, 049 (15) | 2 401 (6) |
| 60–69 | 47, 306 (26) | 7 073 (17) |
| 70–79 | 53, 184 (29) | 14, 931 (35) |
| 80 + | 32, 353 (18) | 16, 923 (40) |
| **Period, n (%)** | | |
| 2007–2011 | 53, 071 (29) | 9 752 (23) |
| 2012–2016 | 58, 847 (32) | 12, 994 (30) |
| 2017–2021 | 71,420 (39) | 19,487 (46) |
| **Tumor category, n (%)** | | |
| T1 | 167, 865 (92) | 35, 486 (84) |
| ≥T2 | 6 070 (3) | 3 335 (8) |
| Unknown | 9 403 (5) | 3 412 (8) |
| **Anatomical location, n (%)** | | |
| Head and neck | 80, 252 (44) | 20, 832 (49) |
| Trunk | 14, 642 (8) | 4 421 (11) |
| Extremities | 41, 559 (22) | 7 667 (18) |
| Undefined | 27, 801 (15) | 3 397 (8) |
| Unknown | 19 ,804 (11) | 5 916 (14) |

observed in men over 80, reaching 1300 per 100,000 in 2021. The annual relative increase varied by age. The APC and AAPC varied by age group, as displayed in Table 2a. For the youngest age groups, a decrease in incidence rate was observed for men aged 20–29 and women aged 30–39 while we found no statistically significant changes in women aged 20–29 and men aged 30–39. An increase was observed in all other age groups, most pronounced for females.

The total number of SCC patients in the youngest age groups (20–39) was 174 over the 15-year period. Due to legislation on the disclosure of microdata, we were prohibited from sharing information involving fewer than three observations per group (in this case, annual case numbers). Consequently, it is not possible to calculate an incidence rate or annual trend for these age groups, and they were omitted from the analysis. In the 40–59 age groups, rates were higher for men until 2013, after which they were higher for women (Fig. 2g). In the older age groups (60 +), rates were consistently higher for men than women in the same age groups (Figs. 2g and 2f). As with BCC, the peak incidence rate was observed in men over 80, reaching 989 per 100,000 in 2021. Table 2b shows the APC and AAPC for all SCC cases and each age group by sex. An increase was noted for women aged 40–49 (AAPC 5.0 %, 95 CI: 1.6–8.9), but not for men. For the remaining age groups we found increasing trends, especially in the last two years of the study period.

### 4.2. Tumor category and anatomical location

#### 4.2.1. Tumor category

In BCC cases, 3 % had a T category of ≥T2, while 92 % were classified as T1, and 5 % had an unknown T category. The number of ≥T2 tumors rose from 307 in 2007–700 in 2021 (Fig. 3a), increasing the proportion from 3.2 % to 4.5 % (Fig. 3b).

As superficial BCC tumors with a diameter above 2 cm may still be treated with non-surgical modalities, the epidemiological data on difference tumor growth patterns are of interest in this study. Unfortunately, most BCC cases (61 %) were coded as basal cell carcinoma NOS, though fewer at the end of the study period. Among patients with known morphology, the majority were nodular BCC (30 %), 5 % were superficial BCC and 4 % were infiltrating BCC. Fig. A1 depict the development in different growth patterns in relation to T category from 2007 to 2021. The number of superficial BCC with a T category of ≥T2 increased from seven to 77 while the proportion was comparable (5.4 % and 5.8 % of total superficial BCC) over the years.

For SCC, 8 % of cases were classified as ≥T2. Among the rest, 84 % were T1, and 8 % had an unknown category. The number of ≥T2 tumors increased from 185 in 2007–356 in 2021 (Fig. 3e), but their proportion decreased from 10.5 % to 7.3 % (Fig. 3f).

The age-adjusted incidence rates for each T category group, showed an increase in BCC cases with a T category of T1 from 231 to 303 per 100,000 between 2007 and 2021. In the same period, the ≥T2 BCC incidence rates almost doubled from eight to 15 per 100,000. Regarding SCC, the age-adjusted incidence rates for T1 cases rose from 36 to 93 per 100,000 from 2007 to 2021, while the cases with a tumor category of ≥T2 increased from five to eight per 100,000 (data not shown).

#### 4.2.2. Anatomical location

The head and neck area were the most common location for cases of BCC, accounting for an average 44 % of tumors over the 15-year period. The number of head and neck cases rose from 3954 to 7034 between 2007 and 2021. The age-adjusted incidence for tumors located in the head and neck increased from 105 to 151 per 100,000 over the study period.

Similarly, 49 % of SCC tumors were located in the head and neck area. The number of these tumors increased from 868 in 2007 to 2359 in 2021. For tumors located in the head and neck, the age-adjusted incidence rate rose from 25 to 51 per 100,000 between 2007 and 2021.

Fig. 3c, d, g and h depict the distribution of anatomical location of BCC and SCC cases over the 15 years for men and women separately. As shown, the anatomical distributions are nearly identical for males and females regarding BCC cases. For SCC, the men had a higher rate of

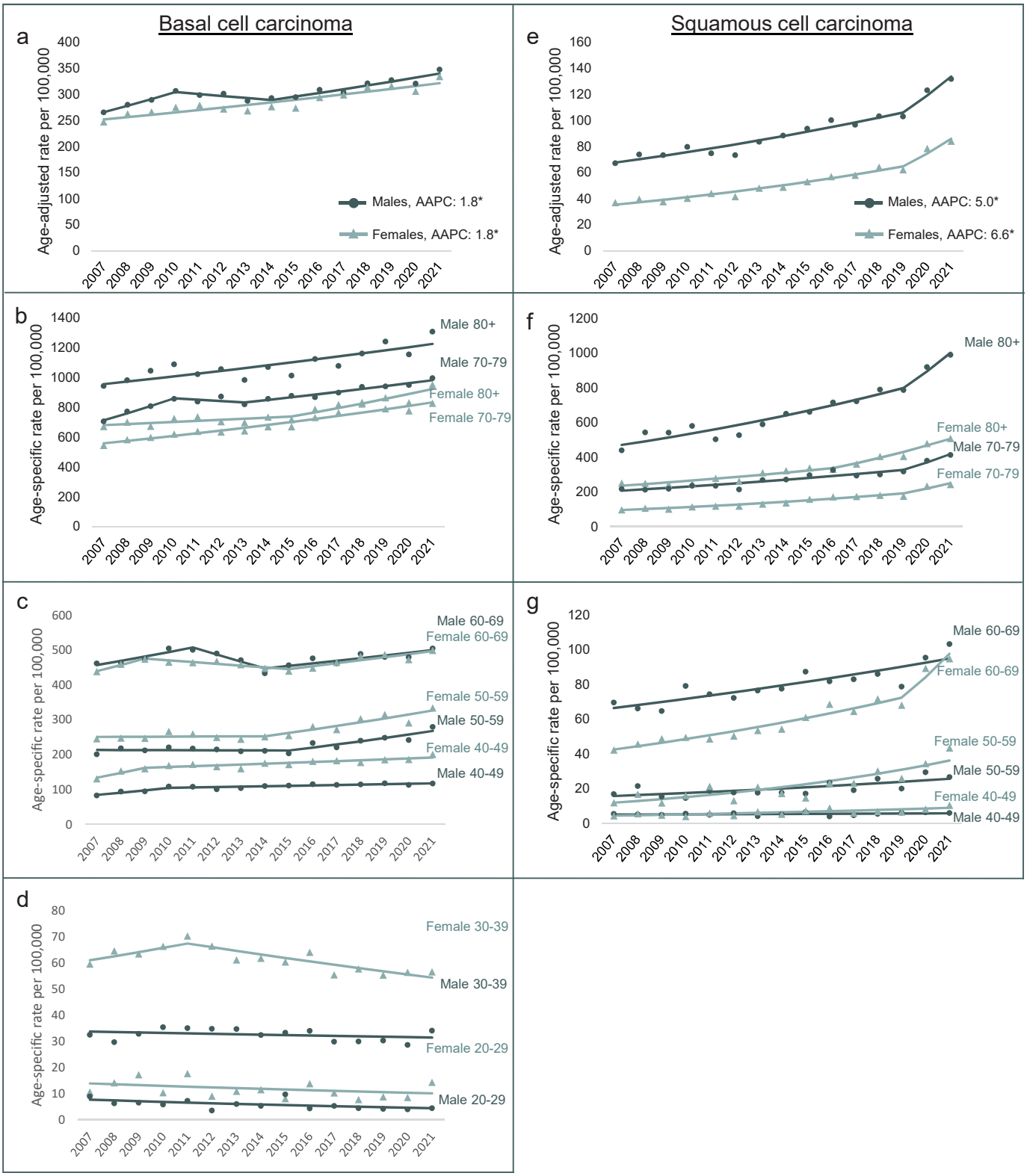


**Fig. 2.** Incidence rates per 100,000 and year. The solid line represents the annual percentage change (APC) and the dots represent the incidence rates in the period 2007–2021 with circles for men and triangles for women. Basal cell carcinoma: a) overall age-adjusted incidence rates, b) age-specific incidence rates for men and women aged 70–80 + , c) age-specific incidence rates for men and women aged 40–69, d) age-specific incidence rates for men and women aged 20–39. Squamous cell carcinoma: e) overall age-adjusted incidence rates, f) age-specific incidence rates for men and women aged 70–80 + , g) age-specific incidence rates for men and women aged 40–69. Please note that the figures have different y-axes.

**Table 2a**
Basal cell carcinoma: age-adjusted and age-speficic incidence rates per 100,000 persons by sex, and trends presented as APC (annual percentage change) and AAPC (average annual percentage change) with 95 % CI (confidence intervals) from 2007 to 2021.

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| | Incidence rates | | APC (95 % CI) | AAPC (95 % CI) | Incidence rates | | APC (95 % CI) | AAPC (95 % CI) |
| | **2007** | **2021** | | | **2007** | **2021** | | |
| **All*** | 265.1 | 347.1 | 2007–2010: **4.7** (2.7; 8.8)<br>2010–2014: −1.3 (−3.2; 0.3)<br>2014–2021: **2.3** (1.7; 3.8) | **1.8** (1.5; 2.2) | 247.1 | 334.0 | 2007–2021: **1.8** (1.1; 2.4) | **1.8** (1.1; 2.4)* |
| **Age**[+] | | | | | | | | |
| 80 + | 943.4 | 1307.5 | 2007–2021: **1.8** (0.7; 3.0) | **1.8** (0.7, 3.0) | 671.4 | 953.4 | 2007–2015: 1.0 (−3.3; 2.2)<br>2015–2021: **3.8** (2.3; 8.5) | **2.2** (1.6; 2.8) |
| 70–79 | 705.8 | 996.5 | 2007–2010: **6.5** (4.1; 12.7)<br>2010–2013: −1.1 (−2.4; 1.4)<br>2013–2021: **2.1** (1.4; 4.4) | **2.3** (2.0; 3.0) | 545.2 | 827.0 | 2007–2021: **2.9** (2.4; 3.5) | **2.9** (2.4; 3.5) |
| 60–69 | 462.0 | 504.9 | 2007–2011: **2.7** (1.1; 7.5)<br>2011–2014: **−4.1** (−5.9; −1.1)<br>2014–2021: **1.6** (0.6; 5.1) | **0.6** (0.2; 1.3) | 438.6 | 499.4 | 2007–2009: **4.0** (1.2; 6.9)<br>2009–2015: **−1.1** (−2.9; 0.4)<br>2015–2021: **1.9** (1.1; 3.3) | **0.9** (0.6; 1.2) |
| 50–59 | 201.3 | 279.9 | 2007–2015: −0.1 (−3.3; 1.1)<br>2015–2021: **4.0** (2.3; 8.1) | **1.6** (1.0; 2.3) | 246.0 | 334.7 | 2007–2014: 0.1 (−6.2; 2.1)<br>2014–2021: **3.7** (1.9; 9.8) | **1.9** (1.1; 2.8) |
| 40–49 | 83.3 | 117.2 | 2007–2010: **7.4** (3.4; 15.2)<br>2010–2021: **1.1** (0.1; 1.6) | **2.4** (1.7; 3.1) | 131.1 | 201.0 | 2007–2009: **10.0** (2.8; 16.8)<br>2009–2021: **1.4** (0.0; 1.9) | **2.6** (1.8; 3.4) |
| 30–39 | 32.5 | 34.2 | 2007–2021: −0.5 (−2.0; 0.9) | −0.5 (−2.0; 0.9) | 59.7 | 56.6 | 2007–2011: 2.5 (−0.1; 8.7)<br>2011–2021: **−2.1** (−3.9; −1.4) | **−0.8** (−1.5; −0.1) |
| 20–29 | 9.0 | 4.5 | 2007–2021: **−3.8** (−7.2; −0.6) | **−3.8** (−7.2; −0.6) | 10.7 | 14.4 | 2007–2021: −2.2 (−6.2; 1.8) | −2.2 (−6.2; 1.8) |

Numbers in **bold** indicate that APC or AAPC is significantly different from zero at α = 0.05
* Age-adjusted to the EU standard population 2013
[+] Age-speficic incidence rates to the actual Danish population of the year in question

**Table 2b**
Squamous cell carcinoma: age-adjusted and age-speficic incidence rates per 100,000 persons by sex, and trends presented as APC (annual percentage change) and AAPC (average annual percentage change) with 95 % CI (confidence intervals) from 2007 to 2021.

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| | Incidence rates | | APC (95 % CI) | AAPC (95 % CI) | Incidence rates | | APC (95 % CI) | AAPC (95 % CI) |
| | **2007** | **2021** | | | **2007** | **2021** | | |
| **All*** | 67.1 | 131.7 | 2007–2019: **3.8** (0.7; 4.7)<br>2019–2021: **12.2** (5.2; 16.5) | **5.0** (4.0; 5.7) | 36.8 | 84.0 | 2007–2019: **5.2** (1.2; 6.3)<br>2019–2021: **15.3** (6.5; 20.3) | **6.6** (5.4; 7.4) |
| **Age**[+] | | | | | | | | |
| 80 + | 439.9 | 989.0 | 2007–2019: 4.5 (−3.0; 17.8)<br>2019–2021: **12.0** (4.0; 18.1) | **5.5** (4.2; 7.0) | 251.6 | 508.4 | 2007–2016: 4.0 (−1.4; 5.5)<br>2016–2021: **8.5** (6.1; 14.8) | **5.6** (4.7; 6.5) |
| 70–79 | 217.2 | 413.6 | 2007–2019: 3.9 (−2.0; 5.6)<br>2019–2021: **13.0** (4.7; 19.2) | **5.1** (3.8; 6.1) | 98.6 | 243.4 | 2007–2019: 6.0 (−1.8; 20.5)<br>2019–2021: **14.3** (5.9; 20.5) | **7.1** (5.8; 8.8) |
| 60–69 | 69.7 | 103.4 | 2007–2021: **2.6** (1.7; 3.6) | **2.6** (1.7; 3.6) | 42.5 | 95.0 | 2007–2019: 4.5 (−0.6; 6.0)<br>2019–2021: **16.1** (5.5; 22.3) | **6.1** (4.7; 7.1) |
| 50–59 | 17.0 | 26.8 | 2007–2021: **3.5** (1.0; 6.5) | **3.5** (1.0; 6.5) | 12.1 | 43.6 | 2007–2021: **8.2** (5.3; 12.2) | **8.2** (5.3; 12.2) |
| 40–49 | 5.7 | 6.1 | 2007–2021: 0.9 (−0.8; 2.7) | 0.9 (−0.8; 2.7) | 4.6 | 10.7 | 2007–2021: **5.0** (1.6; 8.9) | **5.0** (1.6; 8.9) |

Numbers in **bold** indicate that APC or AAPC is significantly different from zero at α = 0.05
* Age-adjusted to the EU standard population 2013
[+] Age-speficic incidence rates to the actual Danish population of the year in question

location in head and neck as compared with other locations, and compared with women. Over the years, an increase in anatomical location on the extremities was observed for both sexes.

## 5. Discussion

This study describes recent trends in the incidence of BCC and SCC, with a focus on T category and location. Both tumor types showed an increase in incidence rates in Denmark from 2007–2021, particularly for SCC in the last two years of the study period. Tumors with a T category of ≥T2 and those in the head and neck area increased substantially for both types of KC.

The incidence of KC is rising around the world [1,19]. Consistent with other studies, our analysis of Danish KC cases shows an ongoing increase in age-adjusted incidence rates for both BCC and SCC [20–23]. A recent Swedish study reported higher incidence rates of BCC (387 per 100,000 women and 423 per 100,000 men in 2017) compared to our findings [24], but the overall APCs are similar, indicating a comparable trend in KC development in the Nordic countries. A study including data on SCC incidence from three European countries (Netherlands, Scotland, Germany) found lower age standardized incidence rates than in our study [25]. However, similar to our findings, they observed increasing rates up until 2020, with rates being higher for men than for women.

In contrast, Australia has seen a decline in treatment rates for KC in men and women younger than 45 years, likely due to early sun awareness campaigns [26,27]. Denmark launched similar campaigns in 2007 [28], which may explain the lack of significant increase in incidence rates for younger age groups (<49 years) in our study, unlike previous findings from 1978 to 2007 [9].

Differences in incidence rates between sexes were evident when stratified by age. Younger women had higher incidence rates for both SCC and BCC compared to younger men, while the opposite was true for older age groups. This pattern aligns with other studies and may be due to differences in sunbathing habits, sunscreen use, and healthcare-seeking behavior [24,29–31]. In addition, since BCC and SCC are primarily caused by chronic UV damage [7,8], and studies, such as Schmitt's [32], have demonstrated a link between outdoor work and SCC development, the differing incidence rates between men and

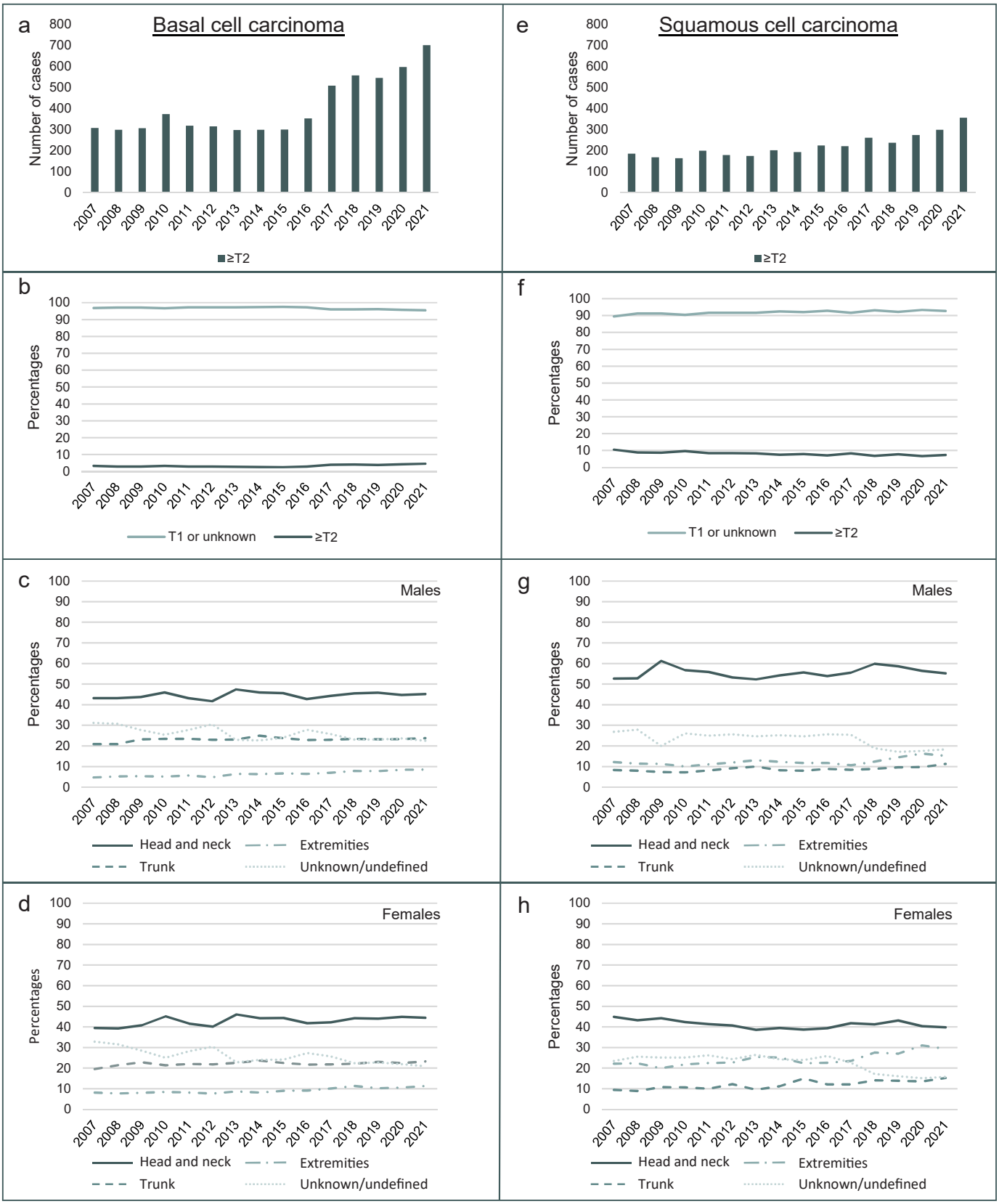


**Fig. 3.** Development of tumor classification and anatomical location 2007–2021. Basal cell carcinoma: a) number of cases with a tumor category ≥T2, b) percentages of tumor category, c) distribution of anatomical location for men, d) distribution of anatomical location for women. Squamous cell carcinoma e) number of cases with a tumor category ≥T2, f) percentages of tumor category, g) distribution of anatomical location for men, h) distribution of anatomical location for women.

women could also be attributed to variations in occupational ultraviolet light exposure, as highlighted in a study by Caroe et al. [33].

Our registry data lacks information on sun exposure. Nevertheless, the large and increasing incidence rates among individuals aged 80 and above, align with the fact that this age group was among the first to vacation in sunnier regions, from the 1960s [34]. The extent of harmful UV-rays in their youth and young adulthood from these travels may contribute to the observed rise in skin cancer rates in the now elderly population. From the results of this study, it is clear that risk of KC peaks in the older age groups, especially the 80 + year olds and especially for men (annual risk of 1.3 % for BCC and 1 % for SCC in 2021). The elderly population is growing, highlighting the potential future burden of this disease [35], and given the increasing life expectancy among men, it is essential to focus on the elevated risk in older age groups.

The steep increase observed in SCC cases from 2019 to 2021 may be partly due to changes in coding practice, such as the reclassification of keratoacanthoma from a benign lesion to well-differentiated SCC in 2020, according to WHO ICD03 version 3.2 [36]. The temporal coincidence with the COVID-19 pandemic is interesting, as other studies found a decrease in diagnosed KC during this time [37,38]. The continuing development in SCC incidence rates should be closely monitored, as other studies suggest that the number of cases will only increase in the future [25,39].

With increasing size and invasiveness, the tumors are assigned a higher T category [40]. We observed an increase in numbers of tumors with a T category of ≥T2 for both types of KC. For BCC, the number of ≥T2 tumors increased by from 307 to 700, which correlates to an increase of 130 %, while the number of ≥T2 SCC cases doubled from 185 to 356. Since the majority of ≥T2 tumors are treated at one of the relatively few plastic surgery hospital departments in Denmark, this will result in an increased treatment burden on these departments, potentially leading to longer waiting times for patients. Another important perspective on the burden of KC is that patients often develop multiple tumors. Our study focuses exclusively on first-time cases. However, research into the total burden of skin cancer cases would undoubtedly be both relevant and desirable. Such research will become feasible in the future, as the Danish NMSC database is expanding to include NMSC cases treated at Danish hospitals. The impending increase in the number of KC with a need for surgery poses significant challenges, in terms of both clinical management and the associated financial burden [41].

During the study period, the proportion of BCC with a T category ≥T2 and/or location in the head and neck area increased, while the proportion of SCC cases in these groups decreased or remained stable. It is widely recognized that SCC is more aggressive than BCC, and results from this study suggest that efforts to diagnose and treat SCC promptly may be effective.

The major strengths of this study include its use of register-based data, providing a comprehensive national overview of KC incidence, which minimizes the risk of selection bias. However, misclassification bias may exist due to potential inconsistencies in clinician-reported data. For instance, the reporting of the T category is not flawless, with up to 8 % of cases classified as unknown.

## 6. Conclusion

This study shows high and increasing age-adjusted incidence rates for both BCC and SCC, with a rise in SCC rates in the last two years of the study period, particularly among elderly males. The number of tumors with a T category of ≥T2 and/or a surgically challenging anatomical location is increasing. However, the decline in proportion of ≥T2 SCC cases suggests improvement in early diagnosis of the disease. Continued awareness, prevention and early detection of KC are critical to mitigate and hopefully reduce the future burden of this disease on society and patients.

## CRediT authorship contribution statement

**Vibeke Koudahl:** Writing – review & editing, Supervision, Conceptualization. **Erik Frostberg:** Writing – review & editing, Methodology. **Anne Sofie Krogh Holdam:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Karina Rønlund:** Writing – review & editing. **Hans Bjarke Rahr:** Writing – review & editing, Supervision, Conceptualization.

## Declaration of Competing Interest

The authors report no conflicts of interest in this work.

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## Appendix

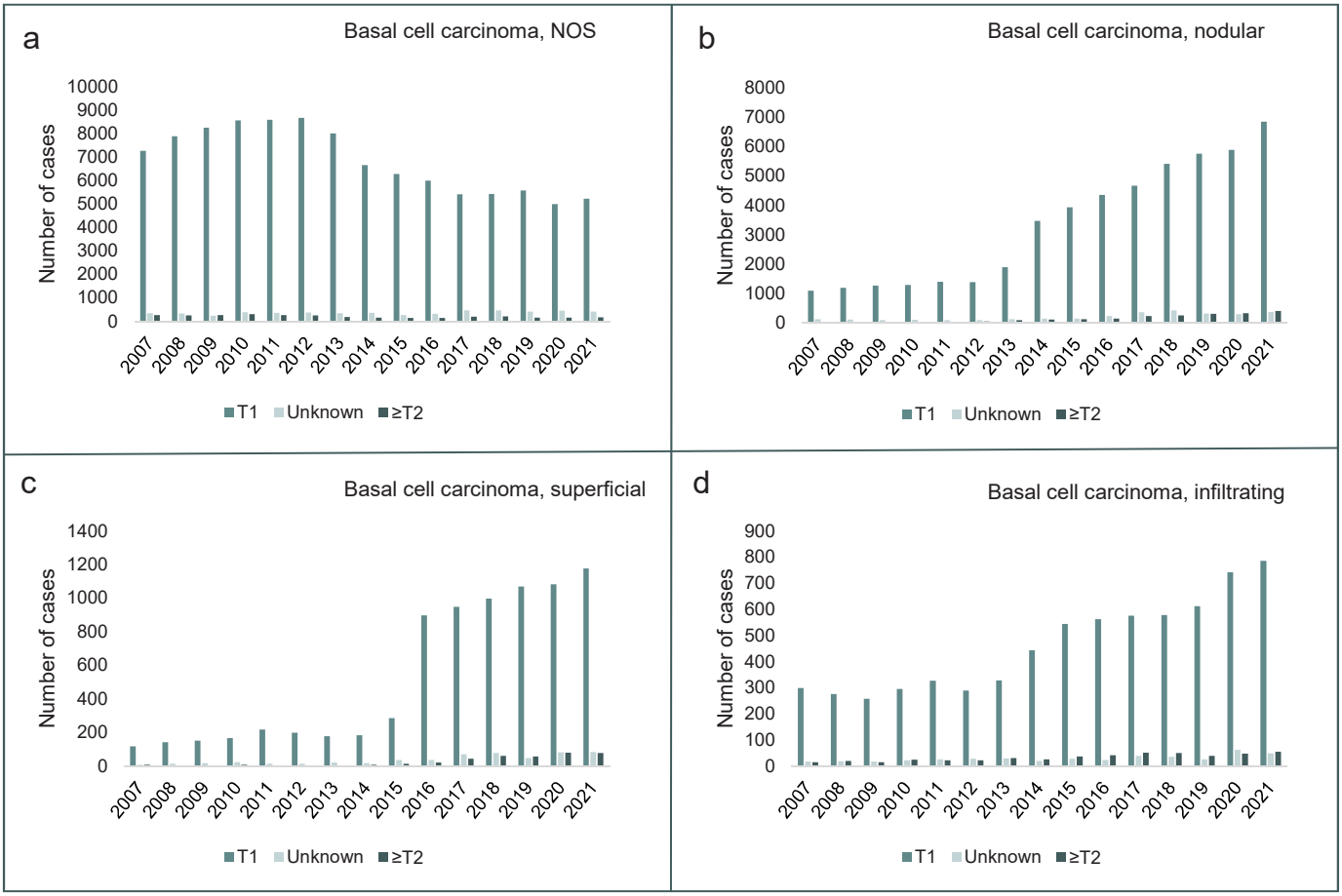


**Figure A1.** Development of basal cell carcinoma growth patterns in relation to T category 2007–2021. a) Basal cell carcinoma, NOS b) basal cell carcinoma, nodular subtype, c) basal cell carcinoma, superficiel subtype, d) basal cell carcinoma, infiltrating subtype. NOS: not otherwise specified

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