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Predictions of skin cancer incidence in the Netherlands up to 2015

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Summary

Background Skin cancer is an important, growing public health problem among white caucasians, causing a heavy burden on dermatologists and general practitioners.

Objectives To predict the future incidence of skin cancer in the Netherlands up to 2015.

Methods Expected numbers of skin cancer cases in the Netherlands up to 2015 were calculated by trend modelling of observed rates for melanoma and squamous cell carcinoma (SCC) between 1989 and 2000 obtained from the Netherlands Cancer Registry and for basal cell carcinoma (BCC) obtained from the Eindhoven Cancer Registry; these rates were then multiplied by the predicted age distributions. Incidence rates were fitted to four different models, and predictions were based on the best fitting model.

Results An increase of 80% in the total number of skin cancer patients is expected in the Netherlands: from 20 654 in 2000 to 37 342 in 2015. The total number of melanoma cases is expected to increase by 99%, with the largest increase for males (males aged 35–64, 111%; males aged ≥65, 139%). Numbers of patients with SCC will increase overall by 80%, mainly among older males and females (increase of 79%) and females aged 35–64 (increase of 93%). The number of cases of BCC will increase by 78%, with the largest increase for the combined groups, those aged 15–64 (males, 66% increase; females, 94% increase), especially for sites other than the head and neck. The contribution of demographic changes (ageing effect) was largest for males with BCC and SCC (35–44%).

Conclusions If incidence rates for skin cancers in the Netherlands continue to increase and population growth and ageing remain unabated, a rise in annual demand for care of more than 5% could occur, putting a heavy burden on general practitioners and dermatologists. In the absence of marked changes in current ultraviolet radiation exposure, these increases will probably continue after 2015.

In fair-skinned caucasian populations, skin cancer has become a significant health problem. In past decades, skin cancer incidence rates have increased steadily,[1–3] leading to a growing demand for healthcare services to inspect suspected lesions and treat patients.

The majority of skin cancers are carcinomas, also referred to as nonmelanoma skin cancers (NMSC), comprising basal cell carcinoma (BCC) and squamous cell carcinoma (SCC). BCC can be a burden for patients and the healthcare system in terms of (often disfiguring) operations and healthcare, but is rarely lethal. About 80% of BCCs are in the head and neck area. SCC can sometimes be fatal for immune compromised patients but this occurs in fewer than 1 in 50 new cases.[4]

Melanoma skin cancers are far less frequent than NMSC but are responsible for the majority of skin cancer deaths. When diagnosed at an early stage melanoma can easily be excised and cured. However, advanced melanoma is very difficult to treat and often fatal.

To determine past trends in the skin cancer epidemic and to predict future incidence rates, numbers of new patients, and demand for healthcare related to skin cancer, we performed trend analyses over the period 1989–2000 using the

Netherlands Cancer Registry and extrapolated these trends up to the year 2015.

The Eindhoven Cancer Registry is one of the few cancer registries that records data on BCC;[5] rates for first primaries are reliable, because of consistent histological verification.

Data and methods

Data

The basis for the predictions was data on new melanomas and SCCs diagnosed in the Netherlands in the period 1989–2000 and new BCCs diagnosed in the catchment area of the Eindhoven Cancer Registry in the same period, population data for the same period and forecasts of the size and structure of the population in the future (Statistics Netherlands, demographic prognoses 2002).

Both the National[1] Cancer Registry and the Eindhoven Cancer Registry are based on ascertainment by pathological laboratories. The Netherlands Cancer Registry is assumed to be complete since 1989, the Eindhoven Cancer Registry since 1970, both with a changing population at risk in later years. In the year 2000, the Netherlands had 7846 317 male and 8017 633 female inhabitants and the Eindhoven Cancer Registry region had 1055 061 male and 1056 972 female inhabitants. Only first primary BCCs, SCCs and melanomas were used for this analysis.[5,6] Only invasive SCCs and melanomas were used for the predictions in this study; *in situ* lesions were excluded.

New cancer cases were grouped into 18 5-year age groups (0–4, 5–9, …, 80–84, 85+ years) and body site distribution for each sex.

Predictions

The predicted numbers of skin cancer cases in the Netherlands in 2005, 2010 and 2015 were estimated by first predicting the incidence rates on the basis of observed rates for 1989–2000, according to the methods described by Dyba *et al.*,[7,8] and then multiplying these rates by the population forecast for these periods, derived from Statistics Netherlands.

Four models of incidence rates as a function of population and time were made; the model fit statistics were compared and the best-fit models were chosen.
The analysed models were:

$$Em_{it} = \alpha_i + \beta_i * t \quad (1)$$
$$Em_{it} = \alpha_i * (1 + \beta * t) \quad (2)$$
$$Em_{it} = \exp(\alpha_i + \beta * t) \quad (3)$$
$$Em_{it} = \exp(\alpha_i + \beta_i * t) \quad (4)$$

where $Em_{it} = c_{it}/n_{it}$ is the expected value of the incidence in age group i and period t, n_{it} is the number of person-years, c_{it} the number of cases and α_i, β and β_i are unknown parameters. The period t can be regarded as a surrogate variable for the changes in the collective impact of various carcinogens to which a population was exposed at a particular point in time. Here, all models are written as a function of calendar time t. Substitution of the year of birth of a cohort for t in these models would yield identical models and predictions. As long as the focus is trend extrapolation, the nonidentifiability problem in age–period–cohort models does not cause further complications.[8]

Model 1 assumes linear changes over time ($\beta_i * t$) and a basic age-specific incidence, α_i, at $t = 0$ (1989). Model 2, being a special case of model 1, can be considered as a linear model with constraints (i.e. with a single age-independent proportionality coefficient β). This model assumes proportional effects for different age groups; the age-specific absolute change in incidence is proportional to the corresponding age-specific baseline rate. Therefore, within the period of prediction this model retains the age pattern of incidence rates existing in the data. Age-specific predictions can therefore be made with greater accuracy.

Model 3 is based on the assumption of the same fractional rise for all age groups, being an exponential change with time [$\exp(\beta * t)$]. Model 4 specifies different fractional changes for different age groups.[7,8]

All models are adjusted for possible over-dispersion and prediction intervals were calculated.[8] Prediction intervals consist of (i) the confidence interval for the expected value of the observation itself, which depends on the fit of the model plus (ii) the variance of the expected incidence given by the parameter values and the year of prediction.[7]

Age groups were 15–34, 35–64, 65+ years and all ages. Analyses according to body site were performed only for BCC; it was not possible to study or predict trends by body site for SCC and melanoma due to the small numbers.

All incidence rates were calculated per 100 000 person-years. For comparison with other countries, the rates were adjusted for age according to the European Standard Population.[9] This adjustment eliminates the effect on rates of changes in age distribution.

Incidence rates were converted into expected numbers for the Netherlands by using population forecasts up to 2015 from Statistics Netherlands. Age-specific incidence rates were multiplied by the predicted sizes of the age groups to calculate expected numbers of new patients. The increase in numbers was calculated relative to the numbers found for the year 2000.

To distinguish between changes in expected numbers of new patients due to an increase in rates and those due to demographic changes we calculated expected numbers using (i) the rates for 2000 applied to the predicted population, and (ii) the observed population in 2000 applied to the predicted incidence rates. The percentage change in these numbers relative to those of 2000 was calculated.

Results

The difference in predicted rates and numbers between the selected models and the other three models was generally small, except when one of the other models showed a lack of fit to the observed data.

Skin cancer incidence rates have increased markedly and will continue to do so. In 2000, BCC was by far the most common type of skin cancer, with about 92 cases per 100 000 person-years among males and around 79 cases per 100 000 person-years among females in the Netherlands. SCC and melanoma were detected less frequently, around 25 and 12 cases per 100 000 person-years for males and 12 and 16 cases per 100 000 person-years for females, respectively (Table 1).

Melanoma

Melanoma incidence rates have increased rapidly in the past 12 years and are expected to keep on doing so in the future (Table 1; Fig. 1a,b). The absolute total number of new cases is expected to be more than 4800 in 2015, compared with around 2400 in 2000.

The number of patients with a cutaneous melanoma is expected to increase considerably for both sexes (238% and 171% increase for males and females, respectively, in 2015 compared with 2000) (Table 1). Increasing incidence rates rather than demographic changes are mainly responsible for these increases (Table 2).

Squamous cell carcinoma

Incidence rates of SCC have increased markedly in the past 12 years, especially for the older age groups, and are expected to continue to do so in the future (Fig. 2a,b; Table 1). For 2015 the predicted age-standardized incidence rates are 33 per 100 000 for males and 17 for females, with the highest rates for the older age groups (Table 1; Fig. 2a,b); this would translate into more than 6000 new cases annually in the Netherlands in 2015, compared with around 3400 new cases per year in 2000 (Table 1).

The future number of SCC patients is affected more by demographic changes among males and by changing incidence rates for females (Table 2).

Basal cell carcinoma

Incidence rates for first primary BCC have increased rapidly in the past decades and are expected to keep rising (Fig. 3a,b; Table 1). Presently incidence rates are the highest for males, especially in the oldest age categories (438 per 100 000 person-years), but the younger females are expected to catch up with them (Table 1; Fig. 3a,b). Incidence rates are expected to increase fairly rapidly in the youngest age groups (15–34 years) as the numbers will probably double by 2015 (Table 1; Fig. 3a,b). For 2015 the predicted annual incidence rates are 122 per 100 000 males and 119 for females; this would imply more than 26 000 new cases of first primary BCC in the Netherlands annually, compared with around 15 000 in 2000 (Table 1).

Analyses according to subsite revealed the head and neck area to be the most common site for first primary BCC, although a marked increase was not observed for this site. Rates for the trunk, arms and legs have been increasing rapidly. In 2000, observed rates for the trunk were slightly higher among males, but on the basis of current trends, women are expected to exhibit higher rates than males in 2015 (Fig. 4a,b).

In 2015, rates for first primary BCC are expected to have more than doubled compared with 2000 for both sexes, and the numbers will be almost double (males 181%, females 175%) (Table 1). The increases in numbers are influenced more by increasing incidence rates than by demographic changes (Table 2), while the combination of the two may cause very marked increases.

Discussion

Skin cancer is one of the most common cancers in white caucasian populations. Rates have increased markedly and are expected to keep rising, with the largest absolute increase in the most common type of skin cancer, BCC. Of special concern are the rates for young people, especially females, which are increasing rapidly for melanoma and BCC. Patterns of observed and expected age-specific incidence differed greatly among the types of skin cancer studied. The observed patterns, with increases in melanoma and BCC, for intermittently exposed body sites would suggest that intermittent ultraviolet (UV) radiation exposure was the main cause of the rising skin cancer rates in the last decades.

The mean age at diagnosis of these tumours is lower for BCC and melanoma than for SCC. Therefore, expected demographic changes will have a larger impact on the numbers of new SCC cases in the future than on BCC and melanoma. Increases in incidence rates will lead to marked increases in expected numbers of BCC and melanoma patients in the future.

The reliability of our estimates depends on many factors: (i) random variation of the predicted rates, which can be derived from the prediction interval around the estimates, and (ii) potential changes in UV radiation exposure whether related to changes in behaviour or not, resulting in altered UV radiation exposure patterns in the population. In the period studied they may not yet be affected by the thinning of the ozone layer. Recently, a report was released that studied the effect of changes in the ozone layer, including potential skin cancer rates.[10] Scenario studies of skin cancer that took into account the restrictions set in the Montreal Protocol predicted an expected 21% increase in numbers of skin cancer patients by 2050 compared with 2002; with the Copenhagen amendments the projected incidence of all skin cancers will increase by 7.5% by 2050, compared with an expected increase of 35% with no restrictions.[10] However, these projections do not take into account patterns in the observed past incidence rates, nor were they adjusted for future changes in demography. Increases in incidence rates were based only on the expected increase in ambient UV radiation.

Table 1 Predicted incidence rates and numbers and 95% prediction intervals of skin cancer by age, sex and type of skin cancer up to 2015

			Rates				Numbers						
	Age (years)	Model[a]	2000 Obs	2005 Expected (95% PI)	2010 Expected (95% PI)	2015 Expected (95% PI)	2000 Obs	2005 Nr (95% PI)	%	2010 Nr (95% PI)	%	2015 Nr (95% PI)	%
Melanoma													
Males	15–34	2	4.7	5.2 (3.9–6.4)	5.5 (4.0–7.0)	5.9 (4.1–7.7)	115	113 (86–139)	99	113 (82–143)	99	124 (87–161)	109
	35–64	4	19.1	23.5 (21.0–26.1)	28.5 (24.6–32.4)	34.6 (28.6–40.7)	598	807 (721–894)	135	1036 (892–1179)	173	1263 (1039–1488)	211
	65+	2	33.7	40.9 (35.6–46.2)	47.7 (41.4–54.0)	54.4 (47.0–61.8)	297	396 (345–447)	133	522 (453–590)	176	709 (613–806)	239
	All	4	12.4	15.7 (14.4–17.0)	19.3 (17.3–21.4)	24.0 (20.7–27.3)	1012	1369 (1256–1482)	135	1811 (1618–2005)	179	2413 (2076–2749)	238
Females	15–34	2	9.6	10.7 (8.9–12.5)	11.7 (9.5–13.9)	12.7 (10.1–15.2)	223	229 (191–267)	103	235 (191–279)	105	264 (210–317)	118
	35–64	4	24.6	28.1 (25.1–31.0)	32.0 (27.6–36.4)	36.7 (30.2–43.2)	769	943 (844–1042)	123	1129 (974–1284)	147	1294 (1063–1525)	168
	65+	2	31.5	34.3 (30.1–38.5)	38.4 (33.4–43.5)	42.6 (36.7–48.5)	409	458 (403–513)	112	541 (471–611)	132	672 (579–764)	164
	All	4	15.7	18.1 (16.8–19.4)	21.1 (19.2–23.0)	24.1 (21.3–26.8)	1406	1673 (1554–1792)	119	1996 (1817–2174)	142	2400 (2130–2671)	171
Squamous cell carcinoma													
Males	15–34	3	0.7	0.7 (0.2–1.1)	0.6 (0.1–1.2)	0.6 (0.0–1.2)	16	15 (5–24)	92	13 (2–24)	82	13 (0–25)	79
	35–64	2	13.9	14.9 (13.0–16.8)	14.8 (12.5–17.1)	14.7 (11.9–17.6)	415	503 (440–566)	121	560 (474–647)	135	557 (450–664)	134
	65+	1	182.5	200.3 (187.9–212.8)	214.6 (199.6–229.6)	228.9 (210.9–247.0)	1590	1958 (1839–2077)	123	2393 (2228–2558)	151	2972 (2742–3203)	187
	All	4	25.4	28.4 (26.8–30.1)	30.5 (28.3–32.7)	32.8 (29.9–35.7)	2021	2513 (2368–2657)	124	3071 (2852–3289)	152	3756 (3424–4088)	186
Females	15–34	3	0.5	0.8 (0.3–1.4)	0.9 (0.2–1.6)	0.9 (0.1–1.8)	13	18 (7–29)	136	18 (4–31)	135	19 (2–37)	147
	35–64	2	10.0	11.8 (10.3–13.4)	13.6 (11.7–15.4)	15.3 (13.1–17.6)	295	394 (342–445)	133	498 (429–566)	169	568 (484–652)	193
	65+	1	70.3	82.3 (76.0–88.5)	91.2 (83.6–98.7)	100.1 (91.1–109.1)	1054	1297 (1203–1391)	123	1510 (1389–1631)	143	1772 (1617–1928)	168
	All	1	11.7	13.8 (12.9–14.7)	15.5 (14.3–16.6)	17.1 (15.8–18.5)	1362	1699 (1591–1806)	125	2018 (1878–2157)	148	2349 (2172–2526)	172
Basal cell carcinoma[b]													
Males	15–34	3	3.2	5.8 (2.9–8.6)	6.6 (2.1–11.1)	7.5 (0.8–14.2)	82[b]	129 (66–192)	157	134 (42–227)	163	157 (17–298)	191
	35–64	2	110	117.2 (107.4–127.0)	127.6 (114.0–141.1)	137.9 (120.5–155.4)	3337[b]	3980 (3648–4313)	119	4727 (4225–5228)	142	5110 (4463–5757)	153
	65+	2	438	489.7 (449.0–530.3)	518.0 (461.2–574.8)	546.4 (472.8–619.9)	3880[b]	4787 (4390–5183)	123	5064 (4509–5618)	131	5341 (4623–6059)	138
	All	3	91.7	102.7 (96.0–109.5)	112.01 (101.7–122.4)	122.3 (107.5–137.0)	7300[b]	9038 (8445–9630)	124	10940 (9930–11951)	150	13186 (11598–14774)	181
Females	15–34	3	13.6	15.8 (10.1–21.6)	22.7 (10.5–34.5)	32.7 (10.5–54.9)	322[b]	351 (224–478)	109	458 (221–696)	142	676 (216–1135)	210
	35–64	2	111	138.1 (130.3–145.8)	147.3 (140.2–154.5)	177.8 (165.5–190.2)	3358[b]	4617 (4358–4876)	137	5328 (5068–5588)	159	6474 (6025–6923)	193
	65+	4	289	341.3 (308.8–373.8)	375.0 (323.9–426.2)	414.5 (338.8–490.2)	3873[b]	3330 (3016–3644)	86	3652 (3161–4143)	94	4028 (3306–4749)	104
	All	1	78.9	95.7 (90.6–100.8)	107.4 (100.4–114.4)	119.1 (110.1–128.1)	7553[b]	9677 (9158–10196)	128	11392 (10628–12156)	151	13238 (12198–14279)	175

[a]Model used for the predictions. Numbers refer to the numbers of the model as described in the Data and methods section. [b]Not available nationwide, numbers calculated based on age-specific rates (in 5-year age categories) from Eindhoven registry. 95% PI, 95% prediction interval; %, total percentage change in numbers compared with the final observed period (2000); (100%, no change; < 100%, decrease in numbers; > 100% increase in numbers); ESR, European standardized incidence rates per 100 000 person-years; Obs, observed rates; Nr, annual number of newly diagnosed tumours in the Netherlands.

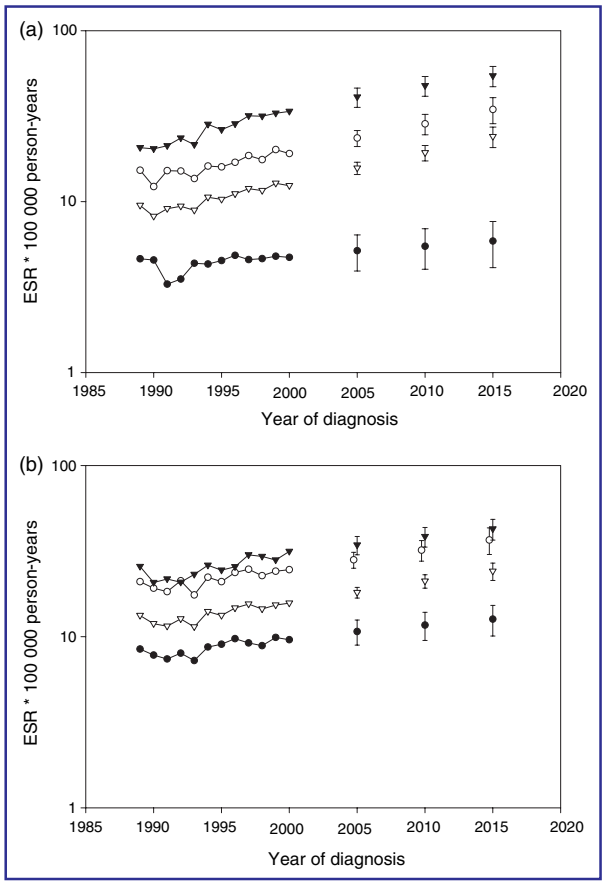

Fig 1. Observed and predicted (extrapolated) age-standardized incidence of cutaneous malignant melanoma with 95% prediction intervals: **(a)** males, **(b)** females; (●, aged 15–34 years; ○, aged 35–64 years; ▼, aged 65 and over; ▽, all ages). ESR, European standardized incidence rates per 100 000 person-years.

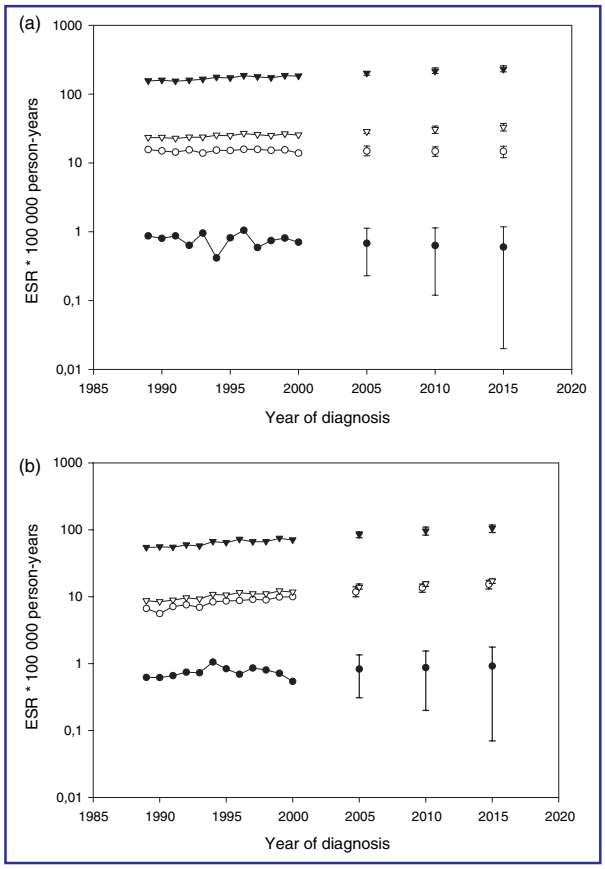

Fig 2. Observed and predicted (extrapolated) age-standardized incidence of squamous cell carcinoma with 95% prediction intervals: **(a)** males, **(b)** females; (●, aged 15–34 years; ○, aged 35–64 years; ▼, aged 65 and over; ▽ all ages). ESR, European standardized incidence rates per 100 000 person-years.

Table 2 Percentage change in annual numbers of new cases of skin cancer compared with the final observed data (2000) due to changes in rates and demography

	Melanoma		Squamous cell carcinoma		Basal cell carcinoma	
	Rates (%)	Demography (%)	Rates (%)	Demography (%)	Rates (%)	Demography (%)
Reference						
2000	100	100	100	100	100	100
Males						
2005	126	108	111	113	112	111
2010	154	115	119	127	122	123
2015	191	122	128	144	133	135
Females						
2005	114	104	117	107	120	107
2010	132	108	130	114	133	113
2015	154	112	144	120	146	120

Demography (%), percentage change in numbers of cases compared with the final observation period (2000) due to demographic projections; projected population numbers are applied to the rates of 2000 (100%, no change; < 100%, decrease in numbers; > 100%, increase in numbers).

Rates (%), increase in numbers of cases compared with the final observation period (2000) due to changes in incidence rates; projected rates are applied to the population in 2000 (100%, no change; < 100%, decrease in numbers; > 100%, increase in numbers).

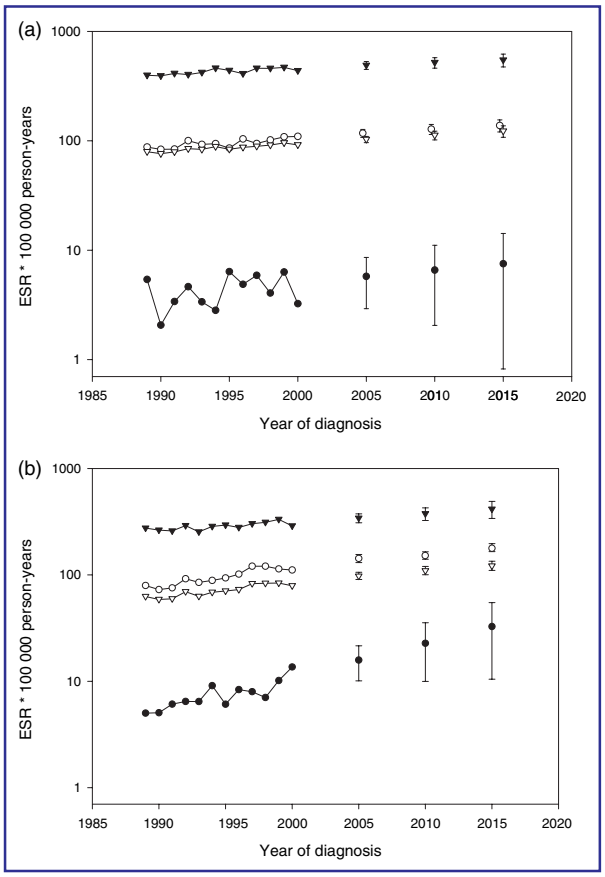

Fig 3. Observed and predicted (extrapolated) age-standardized incidence of basal cell carcinoma with 95% prediction intervals: **(a)** males, **(b)** females; (●, aged 15–34 years; ○, aged 35–64 years; ▼, aged 65 and over; ▽, all ages). ESR, European standardized incidence rates per 100 000 person-years.

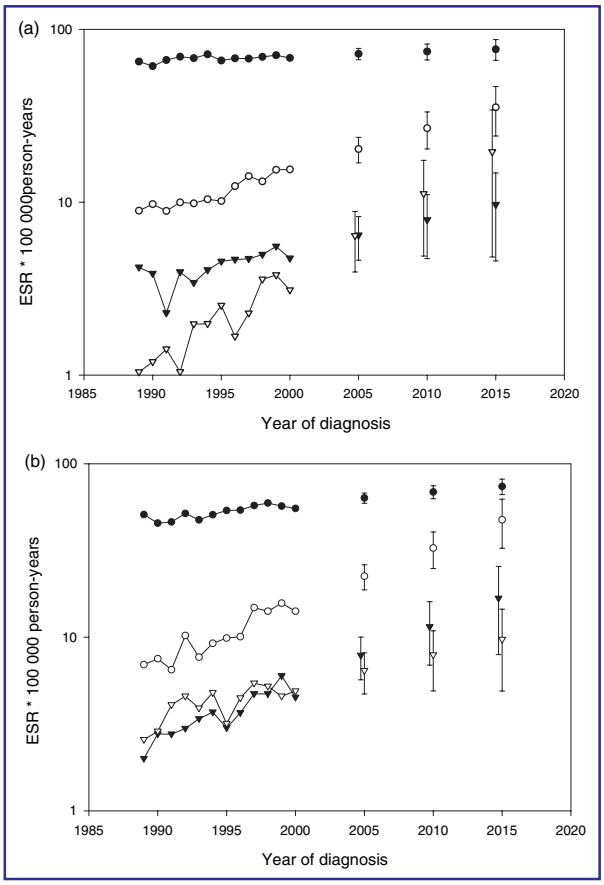

Fig 4. Observed and predicted (extrapolated) age-standardized incidence of site-specific basal cell carcinoma with 95% prediction intervals: **(a)** males, **(b)** females; (●, head and neck; ○, trunk; ▼, arms; ▽, legs). ESR, European standardized incidence rates per 100 000 person-years.

Rates for melanoma are expected to increase for all age groups, but more markedly among the young. This would be in contrast to a previous study investigating trends in incidence and mortality of melanoma across Europe, which seemed to indicate a levelling off of incidence and mortality rates in northern and, to a lesser extent western Europe, especially for the young age groups.[1] When our results are compared with the predicted changes in melanoma incidence in the Nordic countries, the pattern for the Netherlands is most similar to that of Denmark. In the other Nordic countries overall rates seem to stabilize or decrease and expected numbers for the young will decrease instead of increase.[11]

We did not have information on the mean thickness of melanomas. On the basis of observations from other studies we expect the patterns to be similar to those in high-incidence regions, such as Australia, the USA and north-western Europe, where the number of thin melanomas seems to be increasing, while the number of thick melanomas remains stable.[12–15] This caused the mean thickness of the melanomas to decrease over time, which is usually accompanied by improvements in survival.

SCC is commonly thought to be associated with cumulative chronic sun exposure, which supports the observation that rates are highest in the oldest age groups.[16,17] However, a marked increase was observed in females aged 35–64, pointing to a possible increase in sun exposure in this cohort. Whereas intermittent sun exposure has been increasing over the past few decades (holidays and leisure time), probably causing the increases in melanoma and BCC, chronic sun exposure presumably did not, due to less work outdoors. Rates for SCC have been increasing, albeit not as steeply as BCC and melanoma, whereas two decades ago, the increase in the rates for BCC and SCC were comparable.[18] Many *in situ* lesions of SCC (keratoses) are treated and hence do not progress to invasive SCC. The incidence of *in situ* SCC might be increasing more, but as it was not registered it cannot be assessed.

BCC was by far the most common type of skin cancer, with rapidly increasing expected rates for both sexes, especially young females.

Differential changes will also occur in the distribution according to subsite; the majority of BCCs will still occur in the head and neck region, but BCCs on other body sites, such

as the trunk, arms and legs, will increase faster than those in the chronically exposed head and neck region, possibly due to intermittent exposure to UV radiation. As in other studies, remarkable expected increases were found for BCCs on the trunk and legs,[18–20] especially for women, probably due to the increasing popularity of sunbathing and wearing bikinis or even monokinis since the 1960s.

Presently, dermatologists in the Eindhoven area have already observed an increasing number of young female patients with many signs of solar damage and BCCs on the trunk (personal communication).[21] In other parts of the world, similar patterns have been reported, with very moderate increases in the head and neck region and substantial increases for both sexes on the trunk and lower limbs.[18]

The largest increases in incidence rates were found for BCC and melanoma, both of which have been associated with intermittent overexposure to UV radiation.[16,22,23] Moreover, the increases in BCC incidence were found mainly for the intermittently exposed body sites: trunk, arms and legs.[18,20] Rates for SCCs and BCCs in the head and neck area, which are associated with chronic UV radiation exposure, have not increased substantially.[18,20]

Policy implications

It is clear that the predicted rates and the numbers of newly diagnosed patients with various skin cancers should keep activities for primary prevention and early detection high on the public health and clinical agenda in the Netherlands. They will increase the burden on general practitioners, dermatologists and to a lesser extent also (plastic) surgeons.[24] Pathologists will also see an increase in work load, depending on the capacity of GPs and dermatologists to differentiate between skin lesions. Assuming that for each new case another 20–50 patients at increased risk will visit the GP or dermatologist, the demand for detection will increase quite markedly: for a GP this is estimated to increase from one to two patients per day. GPs and dermatologists will have to find ways to deal with this patient demand, which is supposed to double in the next decade.

Unfortunately, these care providers are becoming increasingly scarce due to the combination of restrictions of the numbers of medical students since the mid-1980s (up to 2002), and the growing numbers of female medical care providers working part-time only. Therefore, scenarios are being developed to discuss options for increasing the efficiency of preventive care. Such options include training and employing nurse practitioners or other practitioners, in fact developing new types of preventive service. Teledermatology has the potential to improve the service, but will not make practice more efficient.

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