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Occupation and Thyroid Cancer

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Abstract

Objectives—Numerous occupational and environmental exposures have been shown to disrupt thyroid hormones, but much less is known about their relationships with thyroid cancer. Here we review the epidemiology studies of occupations and occupational exposures and thyroid cancer incidence to provide insight into preventable risk factors for thyroid cancer.

Methods—The published literature was searched using the Web of Knowledge database for all articles through August 2013 that had in their text "occupation" "job" "employment" or "work" and "thyroid cancer". After excluding 10 mortality studies and 4 studies with less than 5 exposed incident cases, we summarized the findings of 30 articles that examined thyroid cancer incidence in relation to occupations or occupational exposure. The studies were grouped by exposure/occupation category, study design, and exposure assessment approach. Where available, gender stratified results are reported.

Results—The most studied (19 of 30 studies) and the most consistent associations were observed for radiation-exposed workers and health care occupations. Suggestive, but inconsistent, associations were observed in studies of pesticide-exposed workers and agricultural occupations. Findings for other exposures and occupation groups were largely null. The majority of studies had few exposed cases and assessed exposure based on occupation or industry category, self-report, or generic (population-based) job exposure matrices.

Conclusion—The suggestive, but inconsistent findings for many of the occupational exposures reviewed here indicate that more studies with larger numbers of cases and better exposure assessment are necessary, particularly for exposures known to disrupt thyroid homeostasis.

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Introduction

The incidence of thyroid cancer has increased nearly 3-fold in the United States and in many countries around the world in the last three decades [1-4]. Increasing attention to small thyroid nodules may explain some of the increased incidence [5]; however, the increased incidence rate is occurring for both large and small size tumors [2-3]. There are few known thyroid cancer risk factors beyond gender and ionizing radiation. For instance, the incidence rate of papillary thyroid cancer, the most common type of thyroid cancer, is 2.5 to 3 times higher among females than among males [3]. By 2019, thyroid cancer is estimated to be the third most common cancer in women of all ages and the second most common cancer in women under the age of 45 in the United States [6]. The reason for the increasing incidence rate is currently unknown, but may point to exogenous risk factors [7-8].

The only recognized exogenous risk factor for thyroid cancer is external ionizing radiation. The evidence comes primarily from studies of childhood exposure [9-11], including cohort studies of atomic bomb survivors [12-13] and of children and infants treated with irradiation for tinea capitis [11] or an enlarged thymus gland [14]. Studies of internal radiation doses, such as studies of radioactive iodine use in medicine [15] and accidental releases from nuclear power plants into the environment (e.g., the Chernobyl accident) [9, 16-19] provide additional support for radiation's role in thyroid cancer.

Much has been learned about the mechanism of radiation-induced thyroid cancer from the Chernobyl accident [19] and prior atomic bomb studies [17-18]; however, potential mechanisms for other environmental causes of thyroid cancer are currently unknown. Thyroid function is controlled by dynamic interrelationships between the hypothalamus, the pituitary, and the thyroid, which maintain circulating levels of the thyroid hormones, triiodothyronine (T_3) and thyroxine (T_4), within a narrow range under normal conditions. Thyroid stimulating hormones (TSH) have been suggested to be important in the development and progression of thyroid cancer [20-21] and increased TSH has shown an association with increased thyroid cancer frequency [22-24]. Chronic stimulation of the thyroid by TSH has been associated with follicular thyroid cancers in animal studies [25-28], although there is uncertainty about how mechanisms may differ between species. The regulation, metabolism, and excretion of thyroid hormones have been shown to be altered by a large number of chemicals found in the workplace [29-34]. For instance, organochlorine pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs), as well as anions including perchlorate and nitrate, have been shown in experimental and human studies to decrease serum levels of thyroid hormones and result in increased thyroid stimulating hormone (TSH) production [25, 33-36]. Little is known, however, about the biological pathway between these chemicals, thyroid disruption, and thyroid cancer.

Here we review the epidemiology studies of thyroid cancer incidence in relation to occupations and occupational exposures to provide insight into potentially preventable thyroid cancer risk factors to identify potential research needs for future research. We used inclusive criteria and report on the findings from all thyroid cancer incidence studies of occupational risk factors with at least five exposed cases. Given the increasing incidence of thyroid cancer in the United States and around the world, the identification of opportunities for prevention is important.

Methods

The published literature was searched using the Web of Knowledge database (apps.webofknowledge.com) for all articles in the database (covers over 100 years) through August 2013 that had in their text “occupation” “job” ”employment” or “work” and “thyroid cancer”. We also searched the Web of Knowledge database for occupational exposure risk factors identified in the initial search, such as thyroid cancer and farming, thyroid cancer and agriculture, and thyroid cancer and pesticides, to ensure we identified all relevant epidemiologic studies of thyroid cancer and occupation. We excluded articles that report on thyroid cancer mortality because of the good survival prognosis of thyroid cancer and occupation and studies and comparison groups within studies with less than 5 exposed thyroid cancer incident cases. We report the study design, which includes industry-based retrospective cohorts (I-RC), industry-based prospective cohorts (I-PC), registry-based retrospective cohorts (R-RC), registry-based case-control studies (R-CC), and case-control (C-C) studies. We report the source of exposure information used in the epidemiologic analyses, which included dosimetry (D), occupation from registry (O-R), occupation from questionnaire (O-Q), occupation from interview (O-I), occupation from employment records (O-ER), self-reported exposure (SR), and job-exposure matrices (JEM). We also report the size of the cohort and the number of cases, the period of investigation, and the effect estimates. Effect estimates for the risk of thyroid cancer incidence were reported as standardized incidence ratio (SIR), odds ratio (OR), relative risk (RR), hazard ratio (HR), and proportional incidence ratio (PIR). An alpha level of 0.05 was set to assess the statistical significance of the associations reported in the studies.

Results are presented for occupations, industries, and exposures with 5 or more incident thyroid cancers. We first present results for three occupational exposures and related occupational groups: radiation-exposed workers and health care occupations; pesticide-exposed workers and agricultural occupations; and textile industry occupations. Lastly, we present results based solely on occupation category (excluding health care, agricultural and textile industry occupations). In each of these four groups, findings are grouped into three categories: cohort studies (regardless of exposure assessment approach), population-based studies with exposure assessed using JEMs or self-reports, and population-based studies based on occupation. When available, results are reported separately by gender. The histologic type of thyroid cancer is also reported when available. The age information available for each study is also reported here.

Results

We found 44 articles that examined thyroid cancer and occupation or occupational exposures. From the total of the articles, we excluded 9 mortality studies [37-45] and five studies with less than 5 exposed thyroid cancer incident cases. We summarize the remaining 30 incident thyroid cancer studies below.

Most studies report the risk for all subtypes of thyroid cancer combined, but where specified, some analyses were restricted to the papillary type of thyroid cancer, the most common subtype. The years of cancer ascertainment ranged from 1945 [39] to 2005 [46]. The studies included industry-based retrospective cohorts (I-RC), industry-based prospective cohorts (I-PC), registry-based retrospective cohorts (R-RC), registry-based case-control studies (R-CC), and case-control (C-C) studies. The study sizes ranged from cohorts with few thyroid cancer cases, to small case-control studies (<50 cases), to a registry linkage study that included approximately 15 million people and over 6,000 incident thyroid cancers. The majority of epidemiologic comparisons in both population- and industry-based studies were based on occupation category. Only four studies [47, 48, 49, 50] linked the subject's occupation to exposure agents using job exposure matrices (JEMs). Only two studies, both of thyroid cancer and radiation exposure, used dosimeter measurements in the exposure assessment [51-52] and two studies used an algorithm of questionnaire responses to derive intensity estimates of pesticide exposure [53, 54].

Radiation-exposed workers and health care occupations

Thyroid cancer incidence risk in relation to radiation-exposed workers and health care occupations was assessed in 19 of the 30 studies (**Table 1**). Two of the nine cohort studies included quantitative measures of radiation dose [51-52]. In a cohort of 103,427 Chernobyl emergency workers who were involved in the cleanup following the accident (all men), Ivanov et al. [51] observed an increased thyroid cancer risk (SIR 3.47, 95%CI: 2.80-4.25). Risk was even stronger among workers involved in early recovery operations 6.62 (95%CI: 4.63-9.09), but there were no statistically significant relationships with quantitative measures of external radiation dose. Jeong et al. [52] observed a significantly increased risk of thyroid cancer among 8,429 male Korean nuclear power workers (SIR = 5.93, 95%CI: 2.84-10.9). In this study, risk increased with increasing radiation exposure based on dosimetry metrics, with an 18-fold increased relative risk among the two cases exposed to more than 100 mSv of radiation as part of their job (RR = 18.51; 95%CI: 1.7-204.3, p-trend = 0.03) and an elevated but not statistically significant excess relative risk per Sievert (ERR 45.2, 95%CI: <-12.1-97.4) [48]. An increased risk of thyroid cancer was also observed by Zielinski et al. [55] among a cohort of Canadian medical workers who were identified using the National Dose Registry of radiation workers when compared to the Canadian general population (SIR 1.74; 90%CI: 1.40-2.14). Wong et al. [56] found no increased risk in a cohort of Chinese textile workers exposed to ten or more years of electromagnetic fields or ionizing radiation.

Significant increases in thyroid cancer risk ranging from 1.5 to 3.3 were also noted in nearly all studies of occupations in cohort studies and in population-based studies with direct interaction with x-ray technology identified by occupation or self-reported exposure (x-ray work, x-ray technologist, etc.) [47-48, 57-60]. More generic characterizations of health care occupations, such as laboratory workers that may or may not have radiation exposure, were often, but not consistently, associated with thyroid cancer risk. Increased risk with health care occupations was observed in a few studies, including female nurses and orderlies (RR = 1.22; 95% CI: 1.01-1.47) [61], female medical technicians (RR = 1.85 95% CI: 1.02-3.35) [61], and female dentists/dental assistants (OR = 13.1 95% CI: 2.1-289) [62]. Increased proportional incidence ratios were also observed by Haselkorn et al. [63] in a registry-based retrospective cohort in Los Angeles County for male dentists (PIR = 388.4; 95%CI: 200.5-678.5), male and female physicians (males: PIR = 240.6; 95% CI: 166.6-336.2; females: PIR = 164.6; 95% CI: 85.0-287.6), and male radiologic technicians (PIR = 425.8; 95%CI: 137.2-993.6). Elevated, but not statistically significant, increased risks were observed for nurses in Norway [64] and Denmark [65] and for laboratory workers in Israel [66]. However, in the largest study, a registry-based retrospective occupational cohort of 15 million people in five Nordic Countries, Pukkala et al [46] did not observe an increase in thyroid cancer risk for any health care occupations.

Pesticide-exposed workers and agricultural occupations

We identified 11 studies that evaluated thyroid cancer incidence risk in relation to occupational pesticide exposure and/or work in agriculture occupations (**Table 2**). In the Agricultural Health Study, a large prospective cohort of pesticide applicators in the U.S. states of Iowa and North Carolina, Beane Freeman et al. [53] observed an increased risk of thyroid cancer incidence for the highest versus lowest category of intensity-weighted lifetime days of atrazine exposure (fourth quartile RR = 4.84; 95%CI: 1.31-17.93; P-trend=0.08), but the trend was not monotonic. In the same cohort, Lee et al. [54] observed a non-statistically elevated risk of thyroid cancer with ever exposure to alachlor, but analyses based on lifetime alachlor exposure-days or intensity-weighted alachlor exposure days showed no trend. No evidence of an increased risk was observed by Lope et al. [49] in a Swedish registry-based retrospective cohort that estimated possible pesticide exposure using a job-exposure matrix or by Hallquist et al. [47] in a Swedish case-control study that assessed self-reported exposure to herbicides and insecticides. Studies of thyroid cancer risk in agricultural occupations (e.g., farmer, agricultural work) were predominantly null [47, 50, 57, 67-68]. However, elevated risks were observed for women in two Swedish registry-based cohort studies: Lope et al. [61] observed increased risk with exposure to wholesale agricultural products (such as live animals, fertilizers, oilseed, and grain) (RR = 2.83; 95% CI: 1.27-6.31) and Pukkala et al. [46] observed an increased risk with women employed as farmers.

Textile industry and occupations

Many of the over 2,000 chemicals used in the textile industry, including dyes, bleaches, transfer agents, as well as endotoxin in cotton dust, are thought to impact health [69-72], but the association with thyroid cancer risk is largely unknown. We identified one cohort study and three population-based studies that reported on the risk of thyroid cancer incidence in the textile industry and occupations (**Table 3**) [46, 56-57, 61]. In a large cohort study of over 250,000 female textile workers in Shanghai, Wong et al. [56] found no significant increases in the risk of thyroid cancer for any of the occupations reported (cotton handling, mixed fiber handling, weaving, cutting/sewing, other manufacturing, or warehouse positions). In the same study, analyses based on a JEM found no significant association with ten or more years of solvent exposure (HR=0.59; 95% CI: 0.30-1.20) or endotoxin exposure (HR=0.76; 95% CI: 0.47-1.20). In the three registry-based population-based retrospective cohorts, only Lope et al. [61] observed an increased risk of thyroid cancer among women tailors and dressmakers (RR = 1.81; 95%CI: 1.00-3.28); Pukkala et al. [46] and Carstensen et al. [57] reported null results.

Other Exposures Assessed by JEMs or Self-report

Only one population-based study, Lee et al. [54], used a JEM to assess exposure (**Table 4**). This Swedish registry-based retrospective cohort included almost 3 million participants and over 2,500 incident cases of thyroid cancer. The risk of thyroid cancer was increased 2-fold for women with probable exposure to solvents, occurring mainly in the shoe industry (RR = 1.91; 95% CI:1.05-3.45) compared to women without solvent exposure; however, no increase in thyroid cancer risk was observed among men with exposure to solvents. No increased risks were observed with JEM-based estimates of exposure to polyhalogenated aromatic hydrocarbons (PAHs), oils, petroleum, arsenic, asbestos, chrome/nickel, or other metals.

Four case-control studies used the subjects' self-report of exposure to occupational agents in analyses of thyroid cancer incidence risk [47, 50, 62, 71]. Wingren et al. [73] found that individuals who reported exposure to video display terminals had a borderline increased risk of thyroid cancer (OR = 2.4; 95% CI: 0.6-10) in a small Swedish case-control study that included 104 papillary thyroid cancer cases. In the expanded case-control of 185 cases published by Wingren et al. [62] shortly thereafter, a similar increase in risk was observed in the ten cases reporting exposure to video display terminals (OR = 2.3; 95% CI: 0.9-5.6). Self-reported exposure to organic solvents was not associated with thyroid cancer risk in a Swedish study by Hallquist et al. [47] with 104 cases, nor was self-reported exposure to chemicals, rubber, and plastics in a large (>1200 cases) Canadian case-control study conducted by Fincham et al. [50].

Other Occupations

We identified 13 studies that examined thyroid cancer incidence risk by occupational category (excluding the aforementioned evaluations of health care, agricultural, and textile occupations) (**Table 4**). Three of these studies were industry-based cohorts. Enewold et al. [74] observed that military men (IRR 1.06, 95%CI: 0.95-1.19) and women (IRR 1.33, 95%CI: 1.18-1.50) had higher incidence rate ratios of thyroid papillary carcinoma, the major subtype of thyroid cancer, compared to the general population. Reynolds et al. [75] found that teachers in a California cohort of school employees also exhibited an increased risk of thyroid cancer (SIR = 1.44, 95% CI: 1.17-1.75). Sathiakumar et al. [76] found an increased risk of thyroid cancer in workers at a petrochemical research facility in Illinois that was not concentrated in a particular occupation or building group (SIR 265, 95%CI: 106-546).

The retrospective registry-based cohorts evaluating thyroid cancer incidence included three Scandinavian studies [46, 57, 61] and a US study [63]. Carstensen et al [57] observed largely null findings for most white and blue collar occupations. Exceptions included an increased incidence of thyroid cancer among buyers and dealers (women only) and among drivers in road transportation (men). Decreased incidence was observed among those who worked in painting and construction (men and women) or as shop assistants (women only). Lope et al [61] noted statistically-significant increased incidence among persons who worked in the electric installation industry (women), paper pulp workers (men), policemen (men), prison and reformatory workers (men) and shop managers (women). Pukkala et al [46] reported an increased incidence of thyroid cancer among building caretakers (women), clerical workers (men), public safety workers (men), and teachers (men), and a decreased incidence for administrators (women), clerical workers (women), hairdressers (women), launderers (women), and sales agents (women). Haselkorn et al. [63] found a statistically significant increased risk of thyroid cancer for many of the white collar occupations evaluated, including male dentists, economists, pharmacists, psychologists, and teachers and female bookkeepers, psychologists, saleswomen, and stenographers. In addition, in a US registry-based case-control study of California male firefighters, Bates [77] found no increased risk of thyroid cancer for firefighters compared to males working in all other occupations.

Five case-control studies of thyroid cancer evaluated occupation. In a large Canadian case-control study of 1,200 thyroid cancer cases, Fincham et al. [50] observed a significantly decreased risk of thyroid cancer among clerical workers and an increased risk of thyroid cancer among those who worked in sales and services or in the wood processing/pulp and paper industry. In a smaller Swedish case-control study of 104 thyroid cancer cases, Wingren et al. [73] observed an increased risk of thyroid cancer among female day nursery personnel. In another Swedish study with 31 cases, Wingren et al. [78] observed an increased risk for male bricklayers. No statistically significant increased thyroid cancer risk was observed for occupations (i.e., cleaner, construction worker, driver, electrical worker, clerical worker, sales, etc.) reported in studies conducted by Hallquist et al. [47] in Sweden or Preston-Martin et al. [79] in China.

Discussion

The strongest evidence linking occupational risk factors to thyroid cancer incidence risk was observed for occupational ionizing radiation. The occupational evidence was observed primarily from large cohort studies of radiation-exposed workers [51-52, 55] or workers with direct interaction with x-ray technology [47-48, 57-60] and from population-based studies that examined risk in relation to x-ray work [47] or ionizing radiation [48] rather than more general health care occupations. Radiation is a biologically plausible risk factor that is supported by strong and consistent epidemiologic evidence from studies of childhood exposure to radiotherapy and fallout from atomic bombings [8]. Although observed less consistently, increased risks in relation to radiation are also observed in adults, as shown here by Richardson [13] in relation to occupational exposures, and within female (but not male) atomic bombs survivors exposed as adults (excess relative rate/Gy = 0.70, 90%CI: 0.20-1.46). The effects observed in occupational studies of working age adults, were generally smaller than the effects observed in studies of children. This parallels the age differential observed in a pooled analysis by Ron et al. [10] of five cohort and two case–control studies, which found an excess risk of thyroid cancer among individuals exposed to external radiation before age 15, but not for individuals exposed at older ages. The age differential in risk is because of the greater radio-sensitivity of the thyroid gland in children than in adults as shown by Ron et al. [11]. Future occupational studies should consider the time window of exposure, especially the early adult years, and potential confounding or effect modification from childhood radiation exposure from medical diagnostics and treatments. To date, a meta-analysis of occupational radiation exposure and thyroid cancer risk has not been published and our findings suggest that there may be sufficient evidence to warrant such an analysis.

Some studies of farmers and other agricultural workers provided some evidence that occupational pesticide exposure or other farm exposures may increase the risk of thyroid cancer incidence. The exposure assessments in these studies were generally limited to evaluating broad categories of pesticides or based on occupation, which may mask specific pesticide or other agricultural exposure associations. Given that the strongest findings of increased thyroid cancer risk were observed by Beane Freeman et al. [53] with quantitative estimates of atrazine exposure among pesticide applicators in the Agricultural Health Study, future studies should include detailed, pesticide-specific exposure assessment. Thyroid-disrupting effects in humans and animals have been observed with several pesticides, including dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene (HCB), and fungicides [31-32, 36, 80]. In analyses of specific pesticides within a cohort of female spouses of pesticide applicators in the Agricultural Health Study by Goldner et al. [80], increased prevalence of hypothyroidism was observed associated with ever use of the organochlorine insecticide chlordane, the fungicides benomyl and maneb/mancozeb, and the herbicide paraquat and increased prevalence of hyperthyroidism was observed with maneb/mancozeb. Among the male pesticide applicators in the cohort, the prevalence of hypothyroidism increased with ever use of several specific herbicides and insecticides, with exposure-response trends observed for alachlor, 2,4-dichlorophenoxyacetic acid, aldrin, chlordane, DDT, lindane and parathion [81]. These and other pesticides, including methoxychlor and endosulfan, have structural similarities to the thyroid hormones and can bind to thyroid hormone transport proteins and receptors, with resulting disruption of thyroid function [32]. Thyroid-disrupting effects, and potentially thyroid cancer, may also result from nitrate exposure from fertilizers that contaminate drinking water of farmers and other agricultural residents [82]. Nitrate competitively inhibits the uptake of iodine, potentially lowering thyroid hormone production, and increasing the TSH release.

Associations between solvent exposure, metal exposure, and thyroid cancer were largely null. An increased risk of thyroid cancer with solvent exposure estimated from a JEM was observed by Lope et al. [49] in one study among women but Hallquist et al. [47] observed no association among men and no association for either sex based on self-reported exposures. Solvents represent a broad group of exposure agents and the risk likely differs by type of solvent. For instance, thyroid hormone levels have been shown to be impacted by phthalates and bisphenol A (BPA), which can occur in solvents, plasticizers and other common household products [83]). The positive findings in some studies, combined with the carcinogenic properties of many solvents [84-86], suggest that additional investigation of the role of solvents in thyroid carcinogenesis is needed. Similarly, additional investigation of the role of metals is needed, because some metals, including cadmium, copper, nickel, and zinc, have shown a propensity to disrupt thyroid homeostasis in animal studies [87-89].

Our focus here was solely on occupational risk factors, but there is also evidence that dietary and environmental exposures may contribute and potentially confound the findings observed here. Dietary factors, especially iodine and nitrate intake, are known to disrupt thyroid homeostasis and have been indicated in thyroid cancer etiology [90-92]. Endocrine disruptors, also implicated in thyroid disruption, can enter the air or water as a byproduct of many chemical and manufacturing processes and when plastics and other materials are burned and have been implicated in thyroid disruption [93]. Areas with volcanic activity, such as Hawaii, the Philippines, and Iceland, are among the regions with the highest incidence of thyroid carcinoma worldwide [93]. Several constituents of volcanic lava (such as vanadium) have been postulated as being involved in the pathogenesis of thyroid cancer [93]. Future studies of occupational risk factors should consider potential confounding from these routes of exposure.

The main limitation of the occupational evidence is the crude exposure assessment approaches used and the small number of incident cases. The majority of studies relied on job or industry titles, self-report, or linked job titles to JEMs that would miss important within-job heterogeneity in exposure. Even if there were true causal associations between these or other occupational agents and thyroid cancer, these studies may have missed elevated risks because of exposure misclassification [94]). Future studies need to be based on more refined exposure assessment protocols. These can involve collecting more task-related information from the subjects themselves (i.e., use of job- and industry-specific modules), industrial hygiene-based exposure assessment, biomarker-based exposure assessment, or combinations of these [95-96]. In addition, we need studies that are both good in quality and large in size and that consider the subtypes of thyroid cancer, which may require pooling and consortium studies, to increase the power to detect small effects. It is also important that studies have enough power to evaluate the risk in men and women separately [97-99], especially because of the large gender differences in incidence. Many of the studies included in this review did not have an adequate population size sufficient to detect an effect, if in fact one exists.

With the exception of radiation, associations between other exposures and thyroid cancer remain speculative. Because occupational exposures are preventable and modifiable and because the incidence of thyroid cancer is increasing, our review suggests that further studies of thyroid cancer and occupational exposures, with sufficient size and high quality exposure assessment, are warranted. In particular, future studies should focus on exposure agents known to disrupt thyroid homeostasis [25, 33-34, 36]. Understanding whether occupational exposures cause thyroid cancer is important, not only for occupational health implications, but because it can also confer improved insight into thyroid cancer trends.

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What this paper adds

- The incidence of thyroid cancer has increased nearly 3-fold in the United States in the last three decades and is 2.5 to 3 times higher among females than among males, but little is known about potential risk factors.
- A review of the published literature for potential occupational risk factors for thyroid cancer incidence found the most consistent associations with exposure to occupational ionizing radiation and found inconclusive but suggestive associations with pesticide-exposed and other agricultural workers.
- Existing studies generally had few exposed cases and predominantly analyzed associations based on occupation or industry categories, with few studies employing quantitative exposure assessment approaches.
- Further studies of thyroid cancer incidence and occupational exposures, with sufficient size and high quality exposure assessment are needed.

Table 1

Reports of the risk of thyroid cancer (TC) incidence of radiation-exposed workers and health care occupations

Reference	Study Design	Study Years	Study Size/Age Information	Country	Source of Exposure Information	Exposure Measure	Overall		Men		Women	
							Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate
Cohort studies												
Ivanov 2008 [51]	I-PC	1986-2003	103427; avg age first employment: 30-35	Russia	O-ER	Chernobyl emergency workers			**87**	**SIR=3.47 (2.80-4.25)**		
					D	Chernobyl emergency workers, risk per unit dose			67	ERR/Gy=−0.29 (−3.18-3.24)		
					O-ER	Chernobyl emergency workers involved in early recovery operations			34	**SIR=6.62 (4.63-9.09)**		
Jeong 2010 [52]	I-PC	1992-2005	16236; avg age 41.3 at end of follow-up for radiation exposed	Republic of Korea	O-ER	Nuclear power radiation workers	**10**	**SIR=5.93 (2.84-10.9)**				
					D	Nuclear power radiation workers, risk per unit dose	**10**	**ERR/Sv=45.2 (<−12.1-97.4)**				
					D	Nuclear power radiation workers, 100+ mSV compa red to 0 mSV	**2**	**RR=18.51 (1.7-204.3)**				
Kjaer 2009 [65]	I-RC	1980-2003	92140; age range: 18-66	Denmark	O-ER	Nurses					76	SIR=1.3 (0.99-1.6)
Li e 2008 [64]	I-RC	1953-2002	43316; age range <35 to 80+	Norway	O-ER	Nurses, risk by time since first exposure (40 years)					18	RR=0.96 (0.36-2.61)
Shaham 2003 [66]	I-RC	1960-1997	4300; avg age: 29.1	Israel	O-ER	Laboratory worker	11	SIR=1.44 (0.72-2.58)			11	SIR=1.61 (0.80-2.87)
						Laboratory worker, 20 year latency					5	SIR=4.86 (1.58-11.3)
Sigurdson 2003 [58]	I-PC	1983-1998	90305; age range: <18 to not reported	United States	O-I	Radiologic technologist	124	**SIR=1.61 (1.34-1.88)**	17	**SIR=2.23 (1.29-3.59)**	107	**SIR=1.54 (1.24-1.83)**
Wang 1990 [59]	I-RC	1950-1985	27,011 x-ray workers; 25,782	China	O-ER	X-ray workers (diagnostic x-ray)	8	RR=1.7			5	RR=1.7

Reference	Study Design	Study Years	Study Size/Age Information	Country	Source of Exposure Information	Exposure Measure	Overall Exposed N cases	Overall Risk Estimate	Men Exposed N cases	Men Risk Estimate	Women Exposed N cases	Women Risk Estimate
			physicians not using x-ray; avg age first employment: 26 physicians not using x-ray; avg age first employment: 26 physicians not using x-ray; avg age first employment: 26 physicians not using x-ray; avg age first employment: 26 physicians not using x-ray; avg age first employment: 26 physicians not using x-ray; avg age first employment: 26									
Wong 2006 [56]	I-RC	1989-1998	3,317; 130 cases; age range: 3-69	China	O-ER linked to JEM	Electromagnetic field, ionizing radiation, 10+ years					64	HR=0.88 (0.59-1.29)
Zabel 2006* [60]	I-PC	1982-1998	73080; age range: <18 to not reported	United States	O-Q	X-ray technologist, holding patients 50 or more times	71	**HR=1.47 (1.01-2.15)**				
						X-ray technologist, had X-rays practiced on self	17	HR=1.46 (0.86-2.46)				
						X-ray technologist, total years worked >25 compared to <5	12	HR=2.29 (0.99-5.32)				
						X-ray technologist, worked before age 20	56	HR=1.02 (0.71-1.47)				
						X-ray technologist, years worked before 1950, >5 compared to 0	11	**HR=3.04 (1.01-10.78)**				
Zielinski 2009 [55]	I-RC	1951-1987	67562; age data not reported	Canada	O-ER	Medical workers	65	**SIR=1.74 (1.40-2.14)****	14	**SIR=2.10 (1.27-3.29)****	51	**SIR=1.66 (1.30-2.10)****
Population-based studies: JEMs and self-reported x-ray work												
Hallquist 1993 [47]	C-C	1980-1989	180 cases; 360 controls; age range: 20-70	Sweden	SR	X-ray work (papillary thyroid cancer)	9	**OR=2.9 (1.1-8.3)**			7	**OR=3.3 (1.2-9.8)**
Fincham 2000 [50]	C-C	1986-1988	1,272 cases; 2,666 controls;	Canada	SR	Ionizing radiation	65	OR=1.03 (0.60-1.77)				
			age data not 2992166;			Electromagnetic fields	19	OR=1.59 (0.80-3.15)				
Lope 2006 [48]	R-RC	1971-1989	age range 24+ to not reported	Sweden	O-R linked to JEM	Electromagnetic fields, >0.35 uT compared to <0.15 uT			155	RR=1.06 (0.85-1.33)	23	**RR=0.64 (0.42-0.97)**
					O-R linked to JEM	Ionizing radiation, medium intensity			23	RR=0.96 (0.63-1.45)		

Reference	Study Design	Study Years	Study Size/Age Information	Country	Source of Exposure Information	Exposure Measure	Overall: Exposed N cases	Overall: Risk Estimate	Men: Exposed N cases	Men: Risk Estimate	Women: Exposed N cases	Women: Risk Estimate
						Ionizing radiation, high intensity					11	**RR=1.85 (1.02-3.35)**
Population-based studies: health care occupations												
Carstensen 1990 [57]	R-RC	1961-1979	Sweden; 4,167 cases; age range: 20-69	Sweden	O-R	Medical and other health service	117	SIR=1.07	22	SIR=1.82	95	SIR=.98
						X-ray operators, lab assistants	12	**SIR=2.44**			9	**SIR=2.24**
Fincham 2000 [50]	C-C	1986-1988	1,272 cases; 2,666 controls; age data not reported	Canada	O-Q	Medicine and health	100	OR=1.08 (0.83-1.39)				
Haselkorn 2000 [63]	R-RC	1972-1995	Los Angeles County; 8820 cases; age range: 0 to 85+	United States	O-R	Dentists			12	PIR=388.4 (200.5-678.5)		
						Physicians			34	PIR=240.6 (166.6-336.2)	12	PIR=164.6 (85.0-287.6)
						Radiologic technicians			5	PIR=425.8 (137.2-993.6)		
Lope 2005 [61]	R-RC	1971-1989	1,066,346 women; 1,496 cases	Sweden	O-R	Nurses and orderlies					121	**RR=1.22 (1.01-1.47)**
						Medical technicians					11	**RR=1.85 (1.02-3.35)**
Pukkala 2009 [46]	R-RC	1961-2005			O-R	Laboratory worker			8	SIR=0.95 (0.41-1.88)	52	SIR=1.08 (0.80-1.41)
			15,000,000; 6,487 cases; age range 30-64	Denmark, Finland, Iceland, Norway, Sweden		Physicians			25	SIR=0.82 (0.53-1.22)	23	SIR=0.88 (0.56-1.32)
						Dentists			12	SIR=1.05 (0.54-1.83)	17	SIR=0.94 (0.55-1.51)
						Nurses					329	SIR=1.08 (0.97-1.20)
						Assistant nurses			8	SIR=1.01 (0.44-2.00)	393	SIR=1.05 (0.95-1.16)
						Other health workers			27	SIR=1.22 (0.80-1.77)	228	SIR=1.04 (0.91-1.18)
Wingren 1995 [62]	C-C	1977-1989	185 cases; 426 controls; age range 20-60	Sweden	O-Q	Dentist/dental assistant					7	**OR=13.1 (2.1-289)**

The risk of thyroid cancer was reported as standardized incidence ratio (SIR), odds ratio (OR), relative risk (RR), hazard ratio (HR), incidence rate ratio (IRR), and proportional incidence ratio (PIR). Bolding indicates a significant effect.

If the confidence interval is not presented with the risk estimate, it is because that information is not available in the original article.

D, Dosimetry; B, Biological Monitoring; O-R, Occupation from registry; O-Q, Occupation from questionnaire; O-I, Occupation from interview; O-ER, Occupation from employment records; SR, self-reported exposure; JEM, job-exposure matrix.

I-RC, industry-based retrospective cohort; I-PC, industry-based prospective cohort; R-RC, registry-based retrospective cohort; RB-CC, registry-based case-control; C-C, case-control study.

* Additional stratified analyses available in publication not presented here.

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Table 2

Reports of the risk of thyroid cancer (TC) incidence of pesticide-exposed workers and agricultural occupations

							Overall	Men	Women			
Reference	**Study Design**	**Study Years**	**Study Size/Age Information**	**Country**	**Source of Exposure Information**	**Exposure Measure**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**
Cohort studies												
Beane Freeman 2011 [53]	I-PC	4	57,310; 29 cases; median age <50	United States	O-I	Atrazine (lifetime intensity weighted-days, 4th quartile vs. 1st quartile)	29	**RR=4.84 (1.31-17.93)**				
Lee 2004 [54]	I-PC	1993-2000	49,980; 16 cases; median age <50	United States	O-Q linked to exposure algorithm	Alachlor (exposed/nonexposed)	10	RR=1.63 (0.42-6.37)				
						Alachlor (lifetime exposure days), Q4 to Q1	10	RR=1.27 (0.10-16.4)				
						Alachlor (intensity weighted exposure days), Q4 to Q1	10	RR=2.89 (0.22-38.7)				
Population-based studies: JEMs and self-reported pesticide exposure												
Lope 2009 [49]	R-RC	1971-1989	2,992,166; 2,599 cases; age range 24+ to not reported	Sweden	O-R linked to JEM	Pesticides/herbicides, possible exposure			84	RR=0.96 (0.77-1.20)	12	RR=0.93 (0.53-1.65)
Hallquist 1993 [47]	C-C	1980-1989	180 cases; 360 controls; age range: 20-70	Sweden	SR-Q	Herbicides	5	OR=0.8 (0.2-2.6)				
					SR-Q	Insecticides	20	OR=1.1 (0.5-2.1)				
Population-based studies: agricultural occupations												
Carstensen 1990 [57]	R-RC	1961-1979	Sweden; 4167 cases; age range: 20-69	Sweden	O-R	Farmers, fisherman, hunters			184	SIR=0.9	40	SIR=0.96
Franceschi 1993 [67]	C-C	1985-1991	191 cases; 2,676 controls; median age 55	Italy	O-I	Farmers	20	RR=0.8 (0.5-1.4)			19	RR=1.1 (0.6-1.8)
Hallquist 1993 [47]	C-C	1980-1989	180 cases; 360 controls; age range: 20-70	Sweden	O-Q	Farmer	24	OR=0.8 (0.4-1.5)				
Pukkala 2009 [46]	R-RC	1961-2005	15,000,000; 6,487 cases; age range: 30-64	Denmark, Finland, Iceland, Norway, Sweden	O-R	Farmer			639	SIR=0.95 (0.88-1.02)	420	**SIR=1.18 (1.07-1.30)**

Reference	Study Design	Study Years	Study Size/Age Information	Country	Source of Exposure Information	Exposure Measure	Overall		Men		Women	
							Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate
						Gardeners			136	**SIR=0.78 (0.66-0.92)**	544	SIR = 1.04 (0.95-1.13)
Fincham 2000 [50]	C-C	1986-1988	1,272 cases; 2,666 controls; age data not reported	Canada	O-I	Farmer	45	OR=0.92 (0.64-1.32)				
Zivaljevic 2003 [68]	C-C	1996-2000	204 cases; 204 controls; median age: 40-49	Serbia	O-I	Agricultural worker					11	OR = 0.74 (0.30-1.79)

The risk of thyroid cancer was reported as standardized incidence ratio (SIR), odds ratio (OR), relative risk (RR), hazard ratio (HR), incidence rate ratio (IRR), and proportional incidence ratio (PIR). Bolding indicates a significant effect.

If the confidence interval is not presented with the risk estimate, it is because that information is not available in the original article.

D, Dosimetry; B, Biological Monitoring; O-R, Occupation from registry; O-Q, Occupation from questionnaire; O-I, Occupati on from interview; O-ER, Occupation from employment records; SR, self-reported exposure; JEM, job-exposure matrix.

I-RC, industry-based retrospective cohort; I-PC, industry-based prospective cohort; R-RC, registry-based retrospective cohort; RB-CC, registry-based case-control; C-C, case-control study.

* Additional stratified analyses available in publication not presented here.

Table 3

Reports of the risk of thyroid cancer (TC) incidence of textile industry and occupations

							Overall		Men		Women	
Reference	Study Design	Study Years	Study Size/Age Information	Country	Source of Exposure Information	Exposure Measure	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate
Cohort studies												
Wong 2006 [56]	I-RC	1989-1998	267400; age range: 30-69	China	O-ER	Cotton handling, processing, spinning, >1 ye ar					26	HR=1.25 (0.80-1.95)
						Mixed fiber handling, >1 year exposure					11	HR=0.67 (0.35-1.26)
						Weaving, >1 year exposure					42	HR=1.05 (0.71-1.53)
						Cutting/sewing, >1 year exposure					12	HR=0.86 (0.47-1.60)
						Other manufacturing, >1 year exposure					9	HR=1.08 (0.53-2.22)
						Warehouse, packing, QC, >1 year exposure					22	HR=0.97 (0.60-1.56)
					O-ER linked to JEM	Endotoxin, 10+ years of exposure					22	HR=0.76 (0.47-1.23)
						Solvents, 10+ years of exposure					9	HR=0.59 (0..30-1.20)
Population-based studies: textile occupations												
Carstensen 1990 [57]	R-RC	1961-1979	Sweden; 4,167 cases; age range: 20-69	Sweden	O-R	Textile workers	23	SIR=0.96	12	SIR=2.01	11	SIR=0.61
Lope 2005 [61]	R-RC	1971-1989	1,066,346 women; 1,496 cases (women); age range: 24 to not reported	Sweden	O-R	Textile workers					13	**RR=1.31 (0.76-2.27)**
						Tailors and dressmakers Knitting mills					11	**RR=1.81 (1.00-3.28)**
						Textile workers					10	RR=1.50 (0.80-2.79)
Pukkala 2009 [46]	R-RC	1961-2005	15,000,000; 6,487 cases; age range: 30-64	Denmark, Finland, Iceland, Norway, Sweden	O-R				53	SIR=0.96 (0.72-1.25)	444	SIR=1.00 (0.91-1.10)

The risk of thyroid cancer was reported as standardized incidence ratio (SIR), odds ratio (OR), relative risk (RR), hazard ratio (HR), and proportional incidence ratio (PIR). Statistically significant effect estimates are in bold.

If the confidence interval is not presented with the risk estimate, it is because that information is not available in the original article.

I-RC, industry-based retrospective cohort or case-cohort; I-PC, industry-based prospective cohort; R-RC, registry-based retrospective cohort; RB-CC, registry-based case-control; C-C, case-control study.

D, Dosimetry; . O-R, Occupation from registry; O-Q, Occupation from questionnaire; O-I, Occupation from interview; O-ER, Occupation from employment records; SR, self-reported exposure; JEM, job-exposure matrix.

Table 4

Reports of the risk of thyroid cancer incidence for other occupational exposures

							Overall		Men		Women	
Reference	**Study Design**	**Study Years**	**Study Size/Age Information**		**Source of Exposure Information**	**Exposure Measure**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**
Population-based studies: JEMs and self-reported exposure												
Lope 2009 [49]	R-RC	1971-1989	2,992,166; 2,599 cases; age range: 24 to not reported	Sweden	O-R linked to JEM	Solvents, probable exposure			31	RR=0.93 (0.65-1.33)	11	**RR=1.91 (1.05-3.45)**
						PAH combustion products, probable exposure			75	RR=1.16 (0.91-1.47)	14	RR=0.86 (0.51-1.46)
						Oil, possible/probable exposure			48	RR=0.82 (0.61-1.10)	39	RR=1.08 (0.79-1.49)
						Petroleum, possible/probable exposure			21	RR=1.12 (0.72-1.72)		
						Chromium/nickel, possible/probable exposure			23	RR=0.94 (0.62-1.43)		
						Arsenic, possible exposure			7	RR=0.97 (0.46-2.04)	7	RR=1.01 (0.48-2.13)
						Mercury, possible/probable exposure					10	RR=1.11 (0.60-2.07)
						Metals, probable exposure			28	RR=1.26 (0.87-1.84)		
Hallquist 1993 [47]	C-C	1980-1989	180 cases; 360 controls; age range: 20-70	Sweden	SR	Organic solvents	24	OR=0.7 (0.3-1.3)				
Fincham 2000 [50]	C-C	1986-1988	1,272 cases, 2,666 controls; age data not reported	Canada	SR	Chemical, rubber, plastics	5	OR=0.96 (0.33-2.79)				
Wingren 1993 [73]	C-C	1977-1987	104 cases; 387 controls; age range: 20-60	Sweden	SR	Solvents			6	OR=2.9 (0.7-12)		
						Video display terminals					6	OR=2.4 (0.6-10)
Wingren 1995 [62]	C-C	1977-1989	185 cases; 426 controls; age range: 20-60	Sweden	SR	Video display terminals					10	OR=2.3 (0.9-5.6)
Industry-based studies: occupations												
Enewold 2011 [74]	I-RC	1990-2004	Military; 743 cases; age range: 20-49	United States	O-R	Military personnel			410	IRR=1.06 (0.95-1.19)	333	IRR=1.33 (1.18-1.50)
Reynolds 1999 [75]	I-RC	1987-1992	268,697; 133 cases; median age: 40-59	United States	O-ER	Administrators	17	SIR=1.01 (0.58-1.61)				
						Teachers	102	**SIR=1.44 (1.17-1.75)**				
Sathiakumar 2001 [76]	I-RC	1986-1997	5641; 7 cases; median age 42	United States	O-ER	Petrochemical processing	7	**SIR=265 (106-546)**				

							Overall		Men		Women	
Reference	**Study Design**	**Study Years**	**Study Size/Age Information**		**Source of Exposure Information**	**Exposure Measure**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**
Population-based studies: occupations												
Bates 2007 [77]	RB C-C	1988-2003	804,000, including 3,659 firefighters; 32 cases (firefighters); age range: 21-80	United States	O-R	Firefighters			32	OR=1.17 (0.82-1.67)		
Carstensen 1990 [57]	R-RC	1961-1979	Sweden; 4,167 cases; age range: 20-69	Sweden	O-R	Armed forces			10	SIR=1.48		
						Buyers, dealers	22	SIR=1.24	14	SIR=0.95	8	**SIR=2.61**
						Clerical workers			55	SIR=1.25	171	SIR=1.08
						Craftsmen			412	SIR=0.89	168	SIR=1.01
						Drivers, road transport	63	**SIR=1.37**	63	SIR=1.39		
						Mechanics			27	SIR=1.09		
						Painters			11	SIR=0.67		
						Painting/construction	5	**SIR=0.36**	5	SIR=0.36		
						Petroleum refineries	5	SIR=3.24	5	SIR=3.85		
						Repair of motor vehicl es			13	SIR=0.82		
						Road passenger transport	14	SIR=1.83	14	SIR=2.14		
						Road transport			28	SIR=1.46		
						Sales workers			90	SIR=1.19	123	SIR=0.86
						Service workers			43	SIR=1.06	218	SIR=0.86
						Shop assistants	101	SIR=0.86	17	SIR=1.59	84	**SIR=0.79**
						Stenographers and typists	37	SIR=0.88	5	SIR=3.47	32	SIR=0.78
						Transport and communication			91	SIR=1.1	31	SIR=0.86
						Truckers			9	SIR=1.18		
						Unskilled manual workers	21	SIR=0.57	18	SIR=0.55	3	SIR=0.78
Fincham 2000 [50]	C-C	1986-1988	1,272 cases; 2,666 controls; age data not reported	Canada	O-Q	Arts and recreation	16	OR=0.71 (0.41-1.24)				
						Clerical workers	288	**OR=0.82 (0.69-0.97)**				

Reference	Study Design	Study Years	Study Size/Age Information		Source of Exposure Information	Exposure Measure	Overall		Men		Women	
							Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate
						Construction worker	44	OR=1.4 (0.94-2.08)				
						Construction worker	44	OR=1.4 (0.94-2.08)				
						Managerial and administrative	173	OR=0.91 (0.74-1.1)				
						Natural science	34	OR=0.91 (0.60-1.4)				
						Sales and service work	253	**OR=1.19 (1.00-1.41)**				
						Transport	24	OR=1.24 (0.74-2.07)				
						Wood processing, pulp, paper-making	14	**OR=2.83 (1.27-6.29)**				
Hallquist 1993 [47]	C-C	1980-1989	180 cases; 360 controls; age range: 20-70	Sweden	O-Q	Cleaner	21	OR=1.8 (0.9-3.5)				
						Construction worker	10	OR=1.5 (0.5-5.1)				
						Driver	8	OR=0.6 (0.2-1.7)				
						Electrical workers	8	OR=1.9 (0.6-6.1)				
						Kitchen staff	22	OR=0.7 (0.4-1.3)				
						Lumberman	17	OR=0.9 (0.4-1.9)				
						Office employee	22	OR=0.9 (0.5-1.5)				
						Saw mill worker	5	OR=1.4 (0.3-5.4)				
Haselkorn 2000 [63]	R-RC	1972-1995	Los Angeles County; 8,820 cases; age range: 0 to 85+	United States	O-R	Bookkeepers					6	**PIR=331.2 (120.9-720.9)**
						Dentists			12	**PIR=388.4 (200.5-678.5)**		
						Economists			8	**PIR=239.8 (103.2-472.5)**	9	PIR=126.1 (57.5-239.4)
						Homemakers					813	**PIR=110.2 (102.7-118.0)**
						Lawyers			29	**PIR=156.2 (104.6-224.4)**	18	PIR=133.1 (78.8-210.3)
						Managers and administrators			187	**PIR=116.9 (100.8-134.9)**	129	PIR=95.0 (79.3-112.9)
						Musicians and composers			12	**PIR=200.2 (103.3-349.8)**		
						Pharmacists			6	**PIR=294.4 (107.5-640.9)**		
						Psychologists			8	**PIR=349.7 (150.6-689.0)**	13	**PIR=220.1 (117.1-376.3)**
						Salesmen/saleswoman					9	**PIR=240.3 (109.7-456.3)**
						Stenographers					9	**PIR=232.6 (106.1-441.6)**
						Teacher, college, university			12	**PIR=250.4 (129.2-437.4)**	7	PIR=95.1 (38.1-196.0)

							Overall		Men		Women	
Reference	Study Design	Study Years	Study Size/Age Information		Source of Exposure Information	Exposure Measure	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate	Exposed N cases	Risk Estimate
Lope 2005 [61]	R-RC	1971-1989	2,845,992; 1,103 male cases; 1,496 female cases; age range: 24 to not reported	Sweden	O-R	Bookkeeping and clerical work	45	RR=0.93 (0.69-1.25)	273	RR=0.94 (0.82-1.07)		
						Bus and tram transport	12	RR=1.38 (0.78-2.44)				
						Electric installation work	14	RR=1.53 (0.90-2.59)	6	**RR=2.53 (1.14-5.64)**		
						engineers and technicians	46	RR=1.19 (0.89-1.60)				
						Government legislative and administrative work	11	RR=1.35 (0.75-2.45)				
						Hairdressers	6	RR=1.96 (0.88-4.38)				
						Logging	29	RR=1.27 (0.87-1.83)				
						Lumberjacks	30	RR=1.42 (0.99-2.04)				
						Manufacture of footwear			6	RR=2.04 (0.91-4.54)		
						Mining and quarrying	6	RR=0.99 (0.44-2.20)				
						Paper pulp workers	7	**RR=2.11 (1.00-4.45)**				
						Policemen	13	**RR=2.12 (1.23-3.66)**				
						Postal services	12	RR=1.34 (0.76-2.36)				
						Prison and reformatory officials	5	**RR=3.56 (1.48-8.57)**				
						Professional and technical work	194	RR=1.05 (0.90-1.23)	334	RR=1.07 (0.95-1.21)		
						Railway transport	32	RR=1.35 (0.95-1.92)				
						Retailing pharmaceuticals			12	RR=1.30 (0.74-2.29)		
						Sales work	80	RR=1.00 (0.79-1.25)	204	RR=1.07 (0.92-1.24)		
						Service and military work	57	RR=0.99 (0.76-1.30)	369	RR=0.97 (0.86-1.09)		
						Shoe cutters, lasters, and sewers					6	RR=2.46 (1.10-5.48)
						Shop manager			11	RR=1.27 (0.70-2.31)	16	**RR=1.80 (1.10-2.94)**
						Social worker					15	RR=1.27 (0.76-2.11)
						Store and warehouse workers			31	RR=1.15 (0.80-1.64)		
						Teachers			6	RR=1.49 (0.67-3.32)		
						Teachers of music, arts, or crafts			5	RR=1.55 (0.65-3.74)		
						Transport and communications work			98	RR=1.11 (0.90-1.37)	Cases	Controls

Reference	Study Design	Study Years	Study Size/Age Information		Source of Exposure Information	Exposure Measure	Overall: Exposed N cases	Overall: Risk Estimate	Men: Exposed N cases	Men: Risk Estimate	Women: Exposed N cases	Women: Risk Estimate
Preston-martin 1993 [79]	C-C	1981-1984	207 controls; 207 cases; median age: 30-34	China	O-I	Clerical workers					8 (3.9%)	10 (4.8%)
						Manufacturing/transport					105 (50.7)	116 (56%)
						Professional/technical work					55 (26.6%)	32 (15.5%)
						Sales work					5 (2.4%)	15 (7.2%)
Pukkala 2009 [46]	R-RC	1961-2005	15,000,000; 6,487 cases; age range 30-64	Denmark, Finland, Iceland, Norway, Sweden	O-R	Administrators			296	SIR=1.09 (0.97-1.22)	86	**SIR=0.78 (0.62-0.96)**
						Artists			31	SIR=0.93 (0.63-1.32)	48	SIR=1.08 (0.79-1.43)
						Artists			31	SIR=0.93 (0.63-1.32)	48	SIR=1.08 (0.79-1.43)
						Beverage workers			8	SIR=1.57 (0.68-3.09)	5	SIR=0.70 (0.23-1.64)
						Bricklayer			46	SIR=1.02 (0.75-1.36)		
						Building caretakers			75	SIR=1.10 (0.87-1.38)	827	**SIR=1.08 (1.01-1.15)**
						Chimney sweeps			6	SIR=1.28 (0.47-2.79)		
						Clerical workers			264	**SIR=1.20 (1.06-1.35)**	1538	**SIR=0.92 (0.88-0.97)**
						Cooks and stewards			18	SIR=0.93 (0.55-1.48)	209	SIR=1.02 (0.89-1.17)
						Drivers			330	SIR=1.03 (0.92-1.15)	21	SIR=1.03 (0.70-1.47)
						Electrical workers			180	SIR=1.02 (0.88-1.18)	75	SIR=1.24 (0.98-1.56)
						Food workers			96	SIR=1.06 (0.86-1.29)	164	SIR=0.99 (0.85-1.16)
						Glass makers			61	**SIR=0.77 (0.59-0.99)**	100	SIR=1.06 (0.87-1.29)
						Hairdressers			19	SIR=1.55 (0.93-2.41)	60	**SIR=0.69 (0.53-0.89)**
						Journalists			14	SIR=0.88 (0.48-1.48)	16	SIR=0.76 (0.43-1.23)
						Launderers			7	SIR=0.87 (0.35-1.79)	62	**SIR=0.76 (0.58-0.97)**
						Military personnel			63	SIR=1.29 (0.99-1.66)		
						Other construction workers			162	**SIR=0.85 (0.73-0.99)**	14	SIR=1.00 (0.54-1.67)
						Other workers			191	SIR=0.90 (0.78-1.03)	324	SIR=0.97 (0.87-1.08)
						Packers			145	SIR=0.96 (0.82-1.13)	150	SIR=0.96 (0.82-1.13)
						Painters			92	SIR=1.05 (0.84-1.28)	6	SIR=0.76 (0.28-1.66)

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							Overall		Men		Women	
Reference	**Study Design**	**Study Years**	**Study Size/Age Information**		**Source of Exposure Information**	**Exposure Measure**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**	**Exposed N cases**	**Risk Estimate**
						Postal Workers			56	SIR=0.91 (0.69-1.18)	242	SIR=1.03 (0.91-1.17)
						Printers			43	SIR=0.83 (0.60-1.11)	39	SIR=0.75 (0.53-1.02)
						Public safety workers			112	**SIR=1.23 (1.04-1.50)**	10	SIR=0.71 (0.34-1.30)
						Religious workers			116	SIR=1.00 (0.84-1.20)	257	SIR=1.00 (0.89-1.13)
						Sales agents			282	SIR=0.99 (0.88-1.11)	161	**SIR=0.82 (0.70-0.96)**
						Shoe and leather workers			22	SIR=1.03 (0.65-1.56)	42	SIR=1.01 (0.73-1.37)
						Smelting workers			86	SIR=0.94 (0.75-1.16)	11	SIR=1.06 (0.53-1.90)
						Teachers			199	**SIR=1.15 (1.00-1.32)**	566	SIR=0.99 (0.91-1.07)
						Technical workers			484	SIR=1.03 (0.94-1.12)	103	SIR=1.07 (0.88-1.30)
						Tobacco workers					6	SIR=0.89 (0.33-1.94)
						Transport workers			112	SIR=1.03 (0.85-1.24)	16	SIR=0.84 (0.48-1.37)
						Waiters			12	SIR=1.13 (0.58-1.97)	188	SIR=0.92 (0.80-1.06)
						Wood workers			332	SIR=0.95 (0.85-1.05)	53	SIR=1.03 (0.77-1.34)
Wingren 1993 [73]	C-C	1977-1989	104 cases; 387 controls; age range: 20-60	Sweden	O-Q	Day nursery personnel					10	**OR=2.6 (1.0-6.6)**
						Mechanics			5	OR=3.2 (0.9-11)		
						Teacher					10	OR=2.9 (0.9-9.2)
						Bricklayer						
Wingren 1997 [78]	C-C	1977-1987	31 cases; 387 controls; age range: 20-60	Sweden	O-Q				6	**OR=14.4 (2.0-105)**		

The risk of thyroid cancer was reported as standardized incidence ratio (SIR), odds ratio (OR), relative risk (RR), hazard ratio (HR), incidence rate ratio (IRR), and proportional incidence ratio (PIR).

Bolding indicates a significant effect.

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* Additional stratified analyses available in publication not presented here.