Original article

Scand J Work Environ Health 2005;31(4):266–276

Quantitative estimates of work-related death, disease and injury in New Zealand

by Andrea 't Mannetje, PhD,[1] Neil Pearce, DSc [1]

't Mannetje A, Pearce N. Quantitative estimates of work-related death, disease and injury in New Zealand. *Scand J Work Environ Health* 2005;31(4):266–276.

Objectives New Zealand lacks comprehensive statistics on work-related injury and illness, and the impact of adverse work conditions on health is therefore not known. The objective of this study was to make quantitative estimates of the annual number of deaths from work-related disease and injury in New Zealand, as well as estimate the number of incident cases of work-related disease and injury.

Methods Wherever possible, specific data for New Zealand were used, but, where adequate national data were lacking, a combination of New Zealand data and extrapolations from other countries was used. For work-related injury mortality and incidence, published studies and reports of the New Zealand Accident Compensation Corporation were primarily used. For work-related disease mortality, the likely population attributable fractions from overseas studies were mainly used, together with mortality data from New Zealand. For work-related disease incidence, both approaches were used.

Results In New Zealand about 700–1000 deaths were estimated to occur annually from work-related disease and about 100 deaths from work-related injury. About 17 000–20 000 new cases of work-related disease occur annually and about 200 000 work-related accidents result in claims made to the New Zealand Accident Compensation Corporation.

Conclusions Despite their imprecision, these conservative estimates indicate the burden of work-related death, disease, and injury in New Zealand. The estimates by gender, industry, and disease types provide useful information for policy priorities.

Key terms attributable fraction; burden; occupational disease; occupational injury.

Worldwide, 6000 people die each day as a result of their job, according to estimates of the International Labour Organization (1). Of these deaths, 15% are due to accidents at work and 85% to work-related disease. Work-related mortality and morbidity place a heavy burden on society in terms of human hardship and economic costs. Quantifying the number of workers involved is an important step towards recognizing the extent of the problem and identifying starting points for intervention. Most countries do not have good reporting systems in place with which to produce reliable statistics on occupational disease and injury. Methods for quantifying the burden of work-related morbidity and mortality therefore rely on various estimation techniques, making use of a range of data sources and current epidemiologic knowledge on occupational risk factors.

In New Zealand there is a clear lack of meaningful and comprehensive occupational injury and illness statistics (2). Although different national sources of occupational health information exist, including data held by the New Zealand Health Information Service of the Ministry of Health, the Accident Compensation Corporation (ACC), and the Notifiable Occupational Disease System of Occupational Safety and Health in the Department of Labour, none of them give a complete picture of the problem. Here we present quantitative estimates of the annual number of deaths from work-related disease and injury in New Zealand, as well as the number of incident cases of work-related disease and injury. Wherever possible data specific for New Zealand were used, but, where adequate national data were lacking, a combination of New Zealand data and extrapolations from other countries was used. We have attempted to present a range of estimates, based on a range of assumptions, rather than identifying one "best" estimate. Despite their imprecision, these estimates represent the first comprehensive indication of the burden of work-related death, disease, and injury in New Zealand.

1 Centre for Public Health Research, Massey University Wellington Campus, Wellington, New Zealand.

Correnpondence to: Dr Andrea 't Mannetje, Centre for Public Health Research, Massey University Wellington Campus, Private Box 756, Wellington, New Zealand. [E-mail: a.mannetje@massey.ac.nz]

Material and methods

In the following paragraphs, we summarize the different methods used to estimate the burden of (i) work-related disease mortality, (ii) work-related injury mortality, (iii) work-related disease incidence, and (iv) work-related injury incidence. For work-related injury, we mainly relied on published reports, of which the methods will be briefly summarized here. For work-related disease mortality, we used epidemiologic estimation methods previously used for other countries, such as the United States (3) and Finland (4), in combination with New Zealand mortality data. For work-related disease incidence, we used both approaches. Injuries and diseases were only included in the estimates if they involved a worker (primary work-related injury or disease), and subsidiary work-related injury and disease was excluded (injury or disease that happens to a bystander or a visitor to the workplace).

Mortality due to work-related disease

For the estimates of mortality due to work-related disease, we relied on methods previously used for the United States (3) and Finland (4), which were based on population attributable fractions (AF) and national mortality statistics for a selected list of causes of death. The first step was the selection of diseases to include. The list of causes of death associated with occupation, as used previously by Steenland et al (3), included only diseases with a well-established link with occupational exposures (eg, lung cancer, asthma). We used this list (list A) to obtain a conservative or lower bound estimate. Nurminen et al (4) used a more extensive list that also included causes of death for which the occupational link was less established (eg, colon cancer, Parkinson's disease, cerebrovascular disease). We used this list (list B) together with list A for the upper bound estimate. The second step was the estimation of the population attributable fraction (ie, the fraction of a disease that would not have occurred had the occupational risk factors been nonexistent in the population). Attributable fractions are based on the epidemiologic evidence of the relative risk related to an occupational risk factor and the prevalence of this risk factor in the population. Epidemiologic evidence based on the New Zealand population is not extensive enough to allow for New Zealand specific estimates of attributable fraction. We therefore relied on the estimates for gender-specific attributable fraction used in the report of Nurminen et al (4), which were based on studies on the Finnish population and the international literature. If appropriate estimates were not obtainable from Nurminen et al, we used other estimates. In the third step, we extracted the number of deaths for each cause of death in lists A and B in New Zealand during the year 1999 (the most recent year for which national mortality statistics were available) (5). For each cause of death an age range was chosen for which it was likely that occupation could be an attributable factor for the disease. Included were those deaths occurring at 30 years or older, except for diseases of the circulatory system and ulcers (ages 20–69 years) and nonmalignant diseases of the respiratory system (ages 20 years and older). In the final step, we multiplied the gender-specific attributable fractions with the gender-specific total annual number of deaths for each cause, resulting in the estimated annual number of deaths attributable to occupational exposures.

Occupational exposures related to specific diseases

The occupational exposures that were considered for each disease follow, and the attributable fractions used for each disease are listed in table 1. If attributable fractions other than those of Nurminen et al (4) were used, they were specified. The relevant codes of the International Classification of Diseases, 9th revision (ICD-9) are also listed.

Cancer of the oral cavity (ICD-9 141–145): polycyclic aromatic hydrocarbons and hydrocarbon solvents.

Cancer of the pharynx (ICD-9 146–148): welding fumes and hydrocarbon solvents.

Cancer of the esophagus (ICD-9 150): polycyclic aromatic hydrocarbons and hydrocarbon solvents.

Cancer of the stomach (ICD-9 151): grain dust, animal contact, herbicides, diesel fumes.

Cancer of the colon (ICD-9 153): asbestos, welding fumes, soldering fumes and gases.

Cancer of the rectum, rectosigmoid junction and anus (ICD-9 154): asbestos and styrene.

Cancer of the liver, specified as primary (ICD-9 155): inorganic dust (mainly silica), aflatoxins from crops used by the livestock feed processing industry). [We also considered hepatitis B and C infection and hepatocellular carcinoma. Hepatitis B surface antigen carriers have an increased risk for hepatocellular carcinoma. A New Zealand study on 193 hepatocellular carcinoma cases (6) showed that hepatitis B surface antigen carriage in the hepatocellular carcinoma cases was 76.7% [95% confidence interval (95% CI) 64.0–86.6] for the Mãori (N=60), 80.0% (95% CI 64.4–90.9) for Pacific islanders (N=40), 88.5% (95% CI 69.8–97.6) for Asians (N=26), and 6.0% 95% CI 1.7–14.6) for Europeans

Table 1. Estimated annual burden of work-related disease mortality in New Zealand, using attributable fractions. (A = well-established link with occupation, B = less-established link with occupation)

Disease [a]	Link with occupation	Attributable fraction (%)		Annual total deaths (N)		Annual deaths attributable to occupational exposures (N)		
		Men	Women	Men	Women	Men	Women	Total
Malignant neoplasms								
Oral cavity (141–145)	B	1.2	0.3	33	34	–	–	–
Pharynx (146–148)	B	2.0	0.5	32	6	1	–	1
Esophagus (150)	B	6.4	0.2	113	59	7	–	7
Stomach (151)	B	10.3	5.4	206	127	21	7	28
Colon (153)	B	5.6	0.0	352	398	20	–	20
Rectum, rectosigmoid junction and anus (154)	B	3.1	0.1	226	158	7	–	7
Liver, specified as primary (155)	A	4.5	6.3	62	13	3	1	4
Gallbladder (1560)	B	0.2	0.4	4	23	–	–	–
Pancreas (157)	B	13.4	3.5	149	149	20	5	25
Nasal cavities, middle ear and accessory (160)	A	24	6.7	4	5	1	–	1
Larynx (161)	A	9.3	0.5	23	8	2	–	2
Trachea bronchus and lung (162)	A	12.3	2.6	873	569	107	15	122
Pleura including mesothelioma (163)	A	90	25	47	10	42	3	45
Bone and articular cartilage (170)	B	0.6	0.6	7	8	–	–	–
Melanoma of skin (172)	B	4.3	0.4	144	83	6	–	6
Other neoplasm of skin (173 ex SCC,BCC)	A	13.1	3.8	53	22	7	1	8
Female breast (174)	B	.	1.7	–	642	–	11	11
Cervix uteri (180)	B	.	5.9	–	70	–	4	4
Uterus (179,182)	B	.	1.1	–	73	–	1	1
Ovary and other uterine adnexa (183)	B	.	2.1	–	169	–	4	4
Prostate (185)	B	6.0	.	552	–	33	–	33
Bladder (188)	A	14.2	7.1	114	54	16	4	20
Kidney and other unspecified urinary (189)	A	4.7	0.8	95	70	4	1	5
Brain (191)	B	10.6	1.3	116	70	12	1	13
Hodgkin's disease (201)	B	3.9	0.0	9	3	–	–	–
Non-Hodgkin's Lymphoma (200,202)	B	13.5	3.1	179	144	24	4	28
Leukemia (204–208)	A	18.5	2.5	144	102	27	3	30
Mental disorders								
Senile and presenile organic psychotic conditions (290)	B	10	1.8	<243	535	<24	10	<34
Nervous system disorders								
Alzheimer's disease (331)	B	3.4	1.8	6	5	–	–	–
Parkinson's disease (332)	B	16	4.9	93	69	15	3	18
Diseases of circulatory system								
Ischemic heart disease (410–414)	A	18.9	9.1	1128	364	213	33	246
Cerebrovascular disease (430–438)	B	12.1	7.8	206	191	25	15	40
Diseases of respiratory system								
Pneumonia (480–486)	B	1.4	0.3	217	396	3	1	4
Chronic obstructive pulmonary disease (491,492&496)	A	14	3.8	884	720	124	27	151
Asthma (493)	A	17.8	18.4	98	118	17	22	39
Asbestosis (501)	A	100	100	10	–	10	–	10
Pneumoconiosis due to other inorganic dust (503)	A	100	100	1	–	1	–	1
Diseases of digestive and genitourinary system								
Ulcer of stomach and duodenum (531–533)	B	29	29	8	6	2	2	4
Nephritis, nephritic syndrome and nephrosis (580–589) 1/3	A	17.6	2.3	42	42	7	1	8
Total								
All occupational diseases								
Lower bound (conservative) estimate	All A	.	.	.	.	581	111	692
Upper bound estimate	A+B	.	.	.	.	801	179	980
All occupational cancer								
Lower bound (conservative) estimate	All A	.	.	.	.	209	28	237
Upper bound estimate	A+B	.	.	.	.	360	65	425

[a] Code of the International Classification of Diseases in parentheses.

(N=67), corresponding to 54.4% (95% CI 43.2–64.0) for all 193 hepatocellular carcinoma cases. The attributable fraction of hepatitis B surface antigen (HBsAg) carriage for hepatocellular carcinoma was slightly less than the prevalence of HBsAg for hepatocellular carcinoma due to the high estimated relative risk of HBsAg for hepatocellular carcinoma (AF 53.5, 95% CI 42.5–62.9). Steenland et al (3) estimated that 4% of hepatitis B virus infections are due to occupational exposures (eg, health care workers); 4% of the preceding attributable fraction results in an attributable fraction of 2.14 (95% CI 1.7–2.5) for occupation related HBsAg carriage for hepatocellular carcinoma. Hepatocellular carcinoma cases have been estimated to take up 50% of all primary liver cancers in the ICD-9 code 155 (6). We therefore added 1% to the attributable fractions of Nurminen et al (4).]

Cancer of the gallbladder (ICD-9 1560): hydrocarbon solvents.

Cancer of the pancreas (ICD-9 157): polycyclic aromatic hydrocarbons, organic solvents, inorganic dust containing crystalline silica, rubber chemicals including acrylonitrile, ionizing radiation, pesticides, nickel.

Cancer of nasal cavities, middle ear and accessory (ICD-9 160): wood dust, leather dust, hexavalent chromium, nickel. [The attributable fractions were taken from Nurminen et al (4). It was noted that the attributable fractions used by Steenland et al (3) are higher (33–46%).]

Cancer of larynx (ICD-9 161): asbestos, welding fumes.

Cancer of trachea bronchus and lung (ICD-9 162): arsenic, asbestos, beryllium, cadmium, chromium, diesel fumes, nickel, silica, environmental tobacco smoke. [Gender-specific attributable fractions were taken from Steenland et al (3), the attributable fraction for chemical exposures being 6.1–17.3 for men and 2.0 for women; for environmental tobacco smoke the attributable fraction was 0.6% for both men and women.]

Mesothelioma: asbestos.

Cancer of bone and articular cartilage (ICD-9 170): ionizing radiation for air carrier personnel.

Melanoma of the skin (ICD-9 172): diesel engine exhaust for warehouse clerks, sunburns for seafarers, cosmic radiation for airline pilots.

Other malignant neoplasm of the skin (ICD-9 173 excluding squamous-cell and basal-cell skin cancers): ultraviolet radiation from outdoor work.

Female breast cancer (ICD-9 174): ionizing radiation for postmenopausal women and hair dyes for hairdressers.

Cancer of the cervix uteri (ICD-9 180): aromatic hydrocarbon solvents.

Cancer of the uterus (ICD-9 179, 182): sedentary work.

Cancer of the ovaries and other uterine adnexea (ICD-9 183): aromatic hydrocarbon solvents, asbestos, leather dust, diesel or gasoline engine exhaust, hair dyes for hairdressers.

Cancer of the prostate (ICD-9 185): metal dust, especially cadmium dust, herbicides.

Cancer of the bladder (ICD-9 188): textile dyes, paints, pigments, leather, rubber, chlorinated hydrocarbon solvents, polychlorinated aromatic hydrocarbons. [The attributable fraction for men was taken from Nurminen et al (4). That for women in the report of Nurminen et al (4) (AF 0.7) was considered too low in the light of two large studies on European and American women (7, 8). We therefore used an attributable fraction of 7.1% for women (half of that for men).]

Cancer of the kidney and other unspecified urinary cancers (ICD-9 189): gasoline, solvents, cadmium, lead.

Cancer of the brain (ICD-9 191): metal dusts, metal working fluids, lead, aromatic hydrocarbon solvents.

Hodgkin's disease (ICD-9 201): unspecified exposures among farmers. [The attributable fractions were taken from Nurminen et al (4); that for women was considered too low, but because of the low number of deaths for this disease, changing the attributable fraction for women would not change the estimate.]

Non-Hodgkin's lymphoma (ICD-9 200, 202): halogenated hydrocarbon solvents, herbicides, fungicides.

Leukemia (ICD-9 204–208): low-frequency magnetic fields from electrical occupations, benzene. [The attributable fractions were taken from Nurminen et al (4). It was noted that the attributable fraction for men was high compared with that of Steenland et al (3), because Nurminen et al includes low-frequency magnetic fields in electrical occupations].

Vascular dementia in senile and presenile organic psychotic conditions (ICD-9 290): pesticides and fertilizers.

Alzheimer's disease (ICD-9 331): low-frequency magnetic fields in electrical work.

Parkinson's disease (ICD-9 332): pesticides.

Ischemic heart disease (ICD-9 410–414): work strain from shift work, noise, engine exhaust including carbon monoxide, environmental tobacco smoke. [The attributable fractions were taken from Nurminen et al (4). They were comparable to those of Steenland et al (3).]

Cerebrovascular disease (ICD-9 430–438): work strain from shift work, environmental tobacco smoke.

Pneumonia (ICD-9 480–486): welding exposures.

Chronic obstructive pulmonary disease (ICD-9 491, 492, 496): organic dust, microbial dust, endotoxins, welding fumes, environmental tobacco smoke.

Asthma (ICD-9 493): grain dust, hay dust, animal epithelia, hairs or secretions, fodders for agricultural workers, epoxy resins or paint, isocyanates for spray painters and lacquerers, chlorine and acids, solvents, dusts for cleaners, exposures in the plastics and rubber industry, flour dust for bakers and pastry makers, welding fumes, textile dust, exposures for hairdressers, environmental tobacco smoke.

Pneumoconiosis (ICD-9 500–505): asbestos, silica, organic dust. [Attributable fractions of 100% were used, based on the rarity of nonoccupational cases of pneumoconiosis.]

Ulcer of the stomach and duodenum (ICD-9 531–533): *w*ork strain from shift work.

Nephritis, nephritic syndrome and nephrosis (ICD-9 580–589): lead, chromium, silica, oxygenated hydrocarbons.

Mortality due to work-related injury

For this estimate, we included fatal injuries occurring at work and in traffic while working or commuting. The estimates were directly based on a previously published study of work-related fatal injuries during 1985–1994 (9) and on a report on work-related fatal traffic injuries in New Zealand during 1985–1998 (10).

In the work-related fatal injuries study (WRFIS) 1985–1994 (9), potential cases of work-related injury deaths were identified from the electronic national mortality data files of the New Zealand Health Information Service (NZHIS), and the circumstances of each fatal incident were then reviewed directly from coronial files. Excluded were suicide deaths, deaths of persons not of working age, deaths while traveling to or from work, deaths due to traffic crashes on public roads, and deaths of bystanders. The results of the study (9) are considered to be more complete than the records of individual registries, or any combination of the registries, of the New Zealand agencies that register work-related fatalities, such as ACC and Occupational Safety and Health (Department of Labour) (11). To obtain an estimate of the annual number of work-related injuries, we divided the published figures by 10, since the study covered 10 years (1985–1994). For estimates by cause of death, we made use of unpublished results of the study [personal communication from Anne-Marie Feyer] that covered the same period (1985–1994).

The WRFIS study excluded deaths from traffic crashes on public roads. We therefore took the estimates of the annual number of work-related fatal traffic injuries from the report "Work-related Fatal Traffic Injuries in New Zealand 1985–1998" (10). The authors of this report used the following three sources of data to identify potential cases: the New Zealand Health Information Service Mortality Database, the Land Transport Safety Authority Traffic Crash Report Database, and the Accident Compensation Corporation Entitlement Claims database. Potential work-related cases were identified, and work-relatedness was determined through coronial files. The report (10) estimates the number of deaths that occurred while the deceased person was either actively working (working death) or commuting to or from work (commuting death), excluding bystanders.

We calculated the total annual rate of work-related fatal injuries per 100 000 employed, using the employment statistics published in *Labour Market Statistics 2002* (12), for the year 1999.

Incidence of work-related disease

Three estimation methods were used for the incidence of work-related disease. For the first method, we used the New Zealand report *Injury Statistics 2001/2002* (13), which covers statistics on ACC claims received and accepted; these claims primarily involve work-related injury but also include some types of occupationally-related disease for which compensation can be claimed from ACC (17 types of illnesses and diseases are listed in schedule 2 of the Injury Prevention, Rehabilitation, and Compensation Act 2001). The ACC data largely exclude injury or disease resulting only in (i) incapacity during the first week (for which ACC is not liable) and (ii) medical treatment (for which the health care provider is normally reimbursed directly). To have a further indication of the severity of cases included in estimation method 1, we used the ACC for work-related illness or disease resulting in weekly compensation payments (13), which comprised about 15% of the claims.

For many work-related diseases, especially multicausal diseases such as cancer and chronic respiratory disease, ACC claims are certain to represent an underreport of the true situation. Therefore, a second method was also applied, in which Finnish incidence rates of

work-related disease (expressed as the number of cases per million population) were used to estimate work-related disease incidence in New Zealand. Finland is a country with one of the best national reporting systems for occupational disease available, and Finnish rates of occupational disease have been used previously to estimate occupational disease incidence for other industrialized countries (14). The Finnish rates represent only diseases reported by physicians or insurance companies to the Finnish Register of Occupational Diseases. A threshold of at least 5 days lost time was assumed, therefore representing the more severe cases only. We used the number of incident cases per year per million population in each age- gender- and disease-specific category in Finland for 1993 (14), multiplied by the New Zealand population counts from 1999 in the same strata, extracted from a report of the World Health Organization (WHO) (5). For occupational asthma, we used Finnish incidence estimates per 100 000 employed between the ages of 20 and 64 years (15).

Since only reported diseases are included, the Finnish rates are also likely to represent an underestimate, especially for cancer. For that reason, we used a third method, in which work-related cancer incidence was estimated through an attributable fraction method, the same as used for our estimate of work-related disease mortality, under the assumption that the attributable fraction for cancer incidence is the same as the attributable fraction for cancer mortality. Cancer incidence (average over the years 1993–1997) was extracted from *Cancer Incidence in Five Continents* (16) for the ages 30 years or older. As in the estimate for the mortality due to work-related disease, a list A and list A+B of occupational cancers were used. We combined the results of the three estimation methods in the following way: the total number of ACC claims for occupational diseases was taken as a lower-bound estimate for the annual burden of new occupational diseases in New Zealand, considering that for some diseases these data would represent an underreport. As an upper bound estimate for the annual burden of incident cases of occupational disease in New Zealand, the highest estimate of methods 1, 2 and 3 was taken.

Incidence of work-related injury

The estimates of the incidence of work-related injury were directly based on the Statistics New Zealand report *Injury Statistics 2001/2002: Work-related Injuries* (13). This report covered work-related injuries that occurred between 1 July 2001 and 30 June 2002 and for which a claim was received and accepted by ACC. The information recorded for each work-related injury was provided by the injured person and the person or organization who provided the first care treatment (eg, ambulance driver, general practitioner, hospital, medical specialist). The events counted were the injuries and not the number of people with an injury. The ratio of injuries to injured persons was 1.14:1. To be consistent with the published report, we report here the number of injuries while noting that it represents a 14% overestimate of the number of injured persons. We excluded all claims for disease and illness, as they are covered in the estimate of the incidence of work-related disease.

ACC is the only source of comprehensive nonfatal work-related injuries in New Zealand, but providing injury statistics is not its primary purpose, and details desirable for such statistics are often absent. For example, ACC statistics do not include specific information on disability or the duration of treatment following an injury. We therefore used the disability percentages recorded for the United States (17) as an approximation. Of all the nonfatal injuries in the United States (13 million per year), 46% were disabling. Of all the disabling injuries, 0.18% resulted in permanent total disability, 12.5% caused permanent partial disability, 30.9% led to temporary total–partial disability, and the rest resulted in temporary disability for 1 to 7 days.

Finally, we compared our estimates with national employment statistics (12), mortality statistics (5), and cancer incidence statistics (16).

Results

Following the methods described above, it was estimated that, in New Zealand, each year there are: (i) about 700–1000 deaths from work-related disease, (ii) about 100 deaths from work-related injury, (iii) about 17 000–20 000 new cases of work-related disease, and (iv) about 200 000 work-related accidents resulting in ACC claims.

In the following paragraphs we present these findings in more detail (ie, by gender, industry, and type of disease or injury) where possible.

Mortality due to work-related disease

Table 1 presents our estimates of the annual burden of work-related disease mortality in New Zealand. For each cause of death, table 1 indicates whether it has a well-established (A) or less-established (B) link with occupation. When only list A diseases are included, the estimated burden of work-related disease is about 700 per year. Also including list B increases the estimate to about 1000 deaths per year. The gender-specific estimates indicate that about 80% of these deaths occur among men. About 30–40% of all deaths are due to occupational cancer (237–425 per year), lung cancer

being the major contributor (122 deaths). Other occupational diseases representing a high burden include ischemic heart disease (246 deaths) and respiratory diseases (205 deaths), especially chronic obstructive pulmonary disease (COPD) (151 deaths). Table 1 also indicates that occupational diseases for which occupational exposure is the principal cause (45 deaths from mesothelioma, 10 deaths from asbestosis, and 1 death from pneumoconiosis) represent less than 10% of the estimated total burden of work-related disease mortality.

Mortality due to work-related injury

Table 2 lists the number of work-related fatal injuries in New Zealand (105 deaths). When traffic accidents on public roads are excluded, 74 deaths occur per year based on the average over a 10-year period between 1985 and 1994 (18). Most (97%) of these deaths occur among men. Agriculture, combined with forestry and fishing, and construction are the industries with the highest number of fatalities due to work-related accidents (34 and 10 deaths, respectively). Mining is, however, the industry with the highest number of accidents per 100 000 workers, followed by agriculture, combined with forestry and fishing. Considering these figures by cause of death indicates that (after traffic accidents), accidents with machinery are the most frequent (17 deaths), followed by water transport accidents (10 deaths) and accidents due to falling objects (10 deaths).

Of the 31 work-related fatal injuries occurring in traffic, 17 occurred while the victim was working and 14 during commuting. Again most of these deaths occurred among men (87%). Most work-related traffic accidents occur in the transport industry (9 deaths) followed by agriculture, combined with forestry and fishing (5 deaths).

Table 2. Estimated annual burden of work-related fatal injuries in New Zealand, excluding bystanders and suicides. (WRFIS = work-related fatal injuries study)

	Annual number of work-related fatal injuries (excluding traffic) (N)	Annual number of work-related fatal traffic injuries (N)			Total annual number of work-related fatal injuries (N)	Total annual rate of work-related fatal injuries [per 100 000 employed (12)] (N per 100 000 employees)
		Working	Commuting	Total		
Gender						
Male	72	16	11	27	99	10.5
Female	2	1	3	4	6	0.8
Industry						
Agriculture, forestry & fishing	33.7	2	3	5	39	25.9
Mining	2.6	–	–	–	3	81.1
Manufacturing	6.7	1	3	4	11	3.8
Electricity, gas & water supply	1.2	1	–	1	2	20.4
Construction	10.4	2	1	3	13	11.9
Wholesale & retail trade	2.5	2	1	3	5	1.6
Accommodation, cafes & restaurants	0.5	–	1	1	2	2.5
Transport & storage	6.7	8	1	9	16	22.9
Communication services	–	1	–	1	1	2.9
Property & business services	1.2	–	1	1	2	1.1
Education	–	–	1	1	1	0.8
Health & community services	–	–	1	1	1	0.8
Other services [a]	6.8	–	1	1	7	4.0
Not specified	2.0				2	–
Cause of death (from WRFIS)						
E919-Accidents caused by machinery	17.0	..	..	..	..	..
E830-8-Water transport accidents	10.0	..	..	..	..	..
E916-Struck accidentally by falling object	9.6	..	..	..	..	..
E880-8-Accidental falls	6.7	..	..	..	..	..
E840-5-Air and space transport accidents	6.3	..	..	..	..	..
E820-5-Motor vehicle nontraffic accidents	4.6	..	..	..	..	..
E925-Accident caused by electric current	2.8	..	..	..	..	..
E960-9-Homicide & injury purposely influenced by others	2.7	..	..	..	..	..
E910-5-Accidents caused by submersion, suffocation & foreign bodies	2.1	..	..	..	..	..
E900-9-Accidents due to natural & environmental factors	1.7	..	..	..	..	..
E800-7-Railway accidents	1.4	..	..	..	..	..
Other	6.0	..	..	..	..	..
Not specified	2.7	..	..	..	..	..
Total	74	17	14	31	105	6.1

[a] Other services include government administration and defense, cultural and recreational services, and personal and other services industries.

Incidence of work-related disease

We estimated that the incidence of work-related disease ranges between 17 000 and more than 20 000 (table 3). For some diseases, such as heart disease and asthma, we were not able to estimate the work-related incidence. Table 3 therefore only includes diseases for which an estimate was obtainable.

For some conditions (eg, musculoskeletal disease), ACC claims represent the best estimate available, whereas for others (eg, work-related cancer) ACC figures clearly represent an underestimate. Only four ACC claims were awarded for occupational cancer, while extrapolating the figures from Finland to New Zealand indicates that 134 cases of occupational cancer should be reported annually. Using the attributable fraction method suggests that 325–773 new work-related cancer cases occur each year. The work-related diseases with the highest incidence include musculoskeletal disease, followed by diseases of the ear, skin disorders, chronic respiratory disease, diseases of the digestive system, and cancer. About 75% of these diseases occur among men.

Incidence of work-related injury

Table 4 presents work-related injuries that happened between 1 July 2001 and 30 June 2002 and for which a claim was received and accepted by ACC. Of the more than 200 000 reported injuries, 74% occurred among men. Sprains and strains are by far the most frequent injury (90 000 claims), followed by open wounds (37 000 claims). Manufacturing is the industry in which most injuries occur, followed by agriculture, combined with forestry and fishing, and wholesale–retail trade. The industry with the most injuries per 100 000 workers was mining, followed by agriculture, combined with forestry and fishing, and manufacturing. Extrapolating disability rates from the United States, we would expect that about half of the reported injuries do not result in disability. Each year, about 12 000 injuries may result in either partial (N=11 900) or total (N=170) permanent disability.

Overall estimates of mortality and morbidity attributable to work-related causes

Finally, the estimates were compared with employment statistics (12), mortality statistics (5), and cancer incidence statistics (16), included in the first rows of table 5. Comparing the estimates presented in tables 1–4 with national statistics shows that, of all deaths, 3–4% are due to adverse work conditions (table 5). About 90% of these deaths are due to work-related disease and

Table 3. Estimated annual burden of work-related disease incidence in New Zealand, using different methods. (ACC = Accident Compensation Corporation)

	Method 1: ACC claims for work-related illness or disease 2001–2002 (13) (N)		Method 2: estimate of expected number of work-related diseases based on Finnish occupational disease rates (14) (N)	Method 3: estimate of expected number of work-related diseases based on attributable fraction method (N)		Methods 1–3 (integrated): estimate number of work-related diseases (N)	
	Severe cases resulting in weekly compensation payments	Total		Lower bound	Upper bound	Lower bound	Upper bound
Gender							
Male	1989	13 184	3721	288	653	13184	>15275
Female	620	4 357	1744	37	120	4357	>4974
Disease							
Disease of the eye	9	316	–	..	..	316	316
Diseases of digestive system	397	1 098	–	..	..	1098	1098
Pneumoconiosis	..	..	269	..	..	..	269
Chronic respiratory disease	..	..	1564	..	..	..	1565
Musculoskeletal disease	2006	10 413 [a]	1446	..	..	10413	10413
Cancer	2	4	134	343	843	4	773
Mental disorders	..	..	166	..	..	..	166
Poisoning	5	223	74	..	..	223	223
Skin disorders	113	1 792	853	..	..	1792	1792
Diseases of ear and mastoid process	–	3 354	958 [b]	..	..	3354	3354
Other diseases	82	341	–	..	..	341	..
Coronary heart disease	..	..	–	..	..	..	..
Infectious disease	..	..	–	..	..	..	..
Asthma	..	..	281	..	..	..	281
Total	2609	17 541	5465	..	..	17541	>20249

[a] Of which 35% are occupational overuse conditions.
[b] Only noise-induced hearing loss.

Table 4. Estimated annual burden of work-related injuries in New Zealand, excluding bystanders and suicides. (US = United States)

	Claims for work-related injury (N)	Claims per 100 employed (1999) (12) (N per 100 employees)
Gender		
Men	153 936	16.3
Women	53 161	6.8
Industry		
Agriculture, forestry & fishing	28 641	19.0
Mining	837	22.6
Manufacturing	47 462	16.6
Electricity, gas & water supply	1 072	10.9
Construction	21 227	19.5
Wholesale & retail trade	26 288	8.6
Accommodation, cafes & restaurants	6 490	8.2
Transport & storage	9 969	14.3
Communication services	2 613	7.6
Finance & insurance	1 307	2.4
Property & business services	10 236	5.6
Education	7 652	6.1
Health & community services	9 788	7.6
Other services	14 602	7.8
Not specified	41 305	
Type of injury		
Sprains & strains	89 750	.
Open wounds	37 674	.
Contusions	19 785	.
Foreign bodies in eyes	12 348	.
More than one type of injury	11 358	.
Fractures	8 019	.
Muscle & tendon injuries	7 047	.
Burns	4 682	.
Other & unspecified injuries	4 283	.
Superficial injuries	3 919	.
Crushing injuries	2 391	.
Eye & orbital injuries	2 228	.
Nerve injuries	1 281	.
Dislocations	963	.
Intracranial injuries	708	.
Traumatic amputations	231	.
Poisoning & toxic effects	223	.
Foreign bodies in ears	71	.
Electrical injuries	61	.
Foreign bodies in other places	45	.
Injury to internal organs	22	.
Injury to blood vessels	8	.
Disability (based on US disability rates)		
No disability	111 832	.
Temporary disability	83 185	.
Permanent partial disability	11 908	.
Permanent total disability	171	.
All	207 097	12.0

10% to work accidents. Annually, 6 per 100 000 employees die due to a work accident, and 12 occupational injuries occur per 100 workers. Of all cancer deaths, 3.1–5.4% are attributable to occupational exposures. All of these estimates are systematically higher for the male population.

Discussion

Limitations of the data

Some methodological issues and uncertainties should be considered before our substantive findings are discussed.

First, the estimates presented are heavily reliant on the diseases that are included. We have attempted to take a conservative approach with a basic list (list A) of diseases with a well-established link with occupation (eg, lung cancer, chronic obstructive pulmonary disease, asthma) and which have been used in virtually all such estimation exercises in other countries. We then supplemented this approach with an additional list (list B) of diseases for which the occupational link is less well-established (eg, colon cancer, Parkinson's disease, cerebrovascular disease). Even this additional list is unlikely to be exhaustive, because new associations of occupational exposures with particular diseases continue to be discovered or have not yet been investigated. Related issues include the exclusion of coronary heart disease deaths after the age of 69 years, the exclusion of contributory causes of death, and the likely underascertainment and underreporting of deaths from conditions such as pneumoconiosis, asthma, and mesothelioma (3). This comment may particularly apply to female workers because most occupational epidemiology studies to date have been restricted to male workers, and it is only relatively recently that "women's occupations" have begun to receive relatively equal attention. Thus hazards in women's work have been underestimated, the result

Table 5 Estimates of work-related deaths, injuries, and diseases, in relation to the total number of workers and deaths in New Zealand.

Estimates	Annual number (see table 1–4)			N per 100 000 employed [a]			N per 100 deaths [b]			N per 100 cancer deaths [c]			N per 100 new cancer cases [d]		
	Men	Women	All	Men	Women	All	Men	Women	All	Men	Women	All	Men	Women	All
Deaths	680–900	117–185	797–1 085	.	.	.	4.9–6.5	0.9–1.4	2.9–3.9	.	.	.	.	.	.
Disease deaths	581–801	111–179	692–980	.	.	.	4.2–5.8	0.8–1.3	2.5–3.6	.	.	.	.	.	.
Cancer deaths	209–360	28–65	237–425	.	.	.	1.5–2.6	0.2–0.5	0.9–1.5	5.2–8.7	0.7–1.7	3.1–5.4	.	.	.
Cancer incidence	325–773	37–120	288–653	.	.	.	.	.	.	.	.	.	2.9–6.7	0.4–1.4	1.8–4.2
Accident deaths	99	6	105	10	1	6	0.7	0.04	0.4	.	.	.	.	.	.
Disease	13 000–15 000	4 000–5 000	17 000–20 000	.	.	.	.	.	.	.	.	.	.	.	.
Injury	50 000	200 000	150 000	6000	12 000	16 000	.	.	.	.	.	.	.	.	.

[a] National statistics: 946 300 employed men, 781 100 employed women for a total of 1 727 400.
[b] National statistics: 13 918 deaths among men ≥20 years of age and 13 586 deaths among women ≥20 years of age anually for a total of 27 504.
[c] National statistics: 4039 cancer deaths among men ≥30 years of age and 3 594 cancer deaths among women ≥30 years of age anually for a total of 7 674.
[d] National statistics: 9 806 cancer incidents among men ≥30 years of age and 8 686 cancer incidents among women ≥30 years of age anually for a total of 18 492.

being underreporting, undercompensation, and underrecognition of the true burden of occupational disease for women (19).

Second, many occupations have been linked with an increased cancer risk, but the etiologically relevant exposures have not been identified. Such occupations were generally not included in our analyses (3). For example, it is well-established that farmers are at increased risk of certain types of cancer (20), and farming is a common occupation in New Zealand. However, the etiologically relevant exposures have not been identified, and therefore these associations were not considered in the analyses.

Third, although most of the limitations of these analyses could be expected to lead to an underestimation of the numbers of work-related deaths, diseases, and injuries, there are some issues that could lead to overestimations, including inadequate adjustment for confounding factors in some of the studies used, lack of recent studies in industries in which exposure levels have been declining (3), and an overestimation of the joint effects of multiple exposures. It should be emphasized that an occupational exposure does not need to be a necessary or sufficient cause of disease for some cases of the disease to be attributable to the exposure. With cancer, for example, there are few, if any, single sufficient causes. Rather, disease occurs due to a combination of exposures, each of which plays a different role in the multistage process of carcinogenesis. Each exposure may increase the risk of cancer occurring, even though the exposure is not necessary or sufficient in itself. Even when the major risk factors are well established (eg, smoking and lung cancer), other exposures may play a role in further increasing the risk of the disease. For example, smoking increases the risk of lung cancer about 10-fold, but asbestos exposure (among smokers) increases the risk still further. In this situation, some cases of lung cancer are attributable to asbestos exposure in that they would not have occurred if the asbestos exposure had not occurred, even if smoking also played a role (21). On the other hand, most published studies probably underestimate the relative risks for occupational exposures because of a nondifferential misclassification of exposure (21).

Finally, the strongest limitation of the analyses presented is the lack of valid New Zealand data on the proportions of the workforce exposed to specific hazards and the level of exposure they receive. For this reason, in some instances (particularly mortality), we have to rely on combining overseas estimates (on exposure levels and the associated relative risks and population attributable fractions) with New Zealand data on the numbers of deaths (or incident cases) from the diseases under consideration. However, where comparable data are available from multiple sources, this approach (of combining overseas attributable fraction estimates with New Zealand data) can be considered conservative. For example, the data on musculoskeletal conditions shown in table 3 indicates that extrapolating from Finnish data to New Zealand (the method used for deaths in table 1 and for disease incidence in table 3) produces an estimate of 1446 incident cases of musculoskeletal disease, compared with the 2006 ACC claims awarded for severe cases and 10 413 ACC claims awarded in all. Similarly, the analyses for bladder cancer estimate that there are about 16 deaths a year (based on a population attributable fraction of 14.2%) among men and 4 among women (7.1%) due to occupational causes (table 1). We have recently conducted an in-depth review of bladder cancer cases among persons aged 20–69 years during 2001 and found that 35 cases among men (31% of those interviewed) and 3 cases among women (8% of those interviewed) were considered to be work-related (22).

Thus, although there is considerable uncertainty associated with the presented estimates, it is likely that they are conservative and underestimate the true burden of work-related death, disease, and injury in New Zealand.

Key findings and concluding remarks

With these caveats in mind, the findings are of considerable interest, and there are several key features that should be noted.

First, the total burden of work-related death, disease, and injury is substantial, being several times higher than the number of deaths occurring in traffic accidents annually in New Zealand. Overall, 3–4% of deaths are work-related, the estimates varying from 4.9–6.5% for men to 0.9–1.4% for women. For cancer, 3.1–5.4% of cancer deaths were work-related, but this figure was once again higher for men (5.2–8.7%) than for women (0.7–1.7%)

Second, 90% of the work-related deaths are due to disease, and only about 10% are due to injury, even though injury has, until recently, been the focus of attention of government agencies such as Occupational Safety and Health in the Department of Labour (23). The most important specific causes of death included cancer (237–425 cases), heart disease (246 cases), and respiratory disease (205 cases).

Third, it should be acknowledged, however, that the situation differs for nonfatal work-related injury and disease, for which the number of reported injuries is about 10 times the number of cases of disease. This estimate is likely to be partly due to the inadequate compensation systems, and inadequate reporting systems, for work-related illness (23). Nevertheless, it indicates that injury is an important cause of work-related morbidity.

In summary, we believe that the estimates that we have presented, despite their limitations, are the most

valid estimates of the burden of work-related death, disease, and injury that have been prepared for New Zealand to date. They indicate that workplace exposures are major causes of morbidity and mortality in New Zealand. They also demonstrate the urgent need to develop more-valid systems for the surveillance of work-related death, disease, and injury in New Zealand in order that more-refined estimates can be developed, the trends over time can be monitored, and the effects of policies and interventions can be assessed.

Acknowledgments

This work was funded in part by a project grant from the Health Research Council of New Zealand, by a contract from the National Occupational Health and Safety Advisory Committee (NOHSAC), and by a Massey University Postdoctoral Research Fellowship.

This work was done in part as a contribution to a NOHSAC report on the burden of occupational disease and injury in New Zealand, and we thank the NOHSAC members (Evan Dryson, Anne-Marie Feyer, Philippa Gander, and Selwyn McCracken), NOHSAC Secretariat (Mark Wagstaffe, Stephanie Kerruish), and Tim Driscoll for their comments on the draft report. The Centre for Public Health Research is supported by a Programme Grant from the Health Research Council of New Zealand.

References

1. Safe work and safety culture. The ILO Report for World Day for safety and health at Work 2004 [report on the Internet]. Geneva: International Labour office (ILO) [cited 2004 March]. Available from: http://www.ilo.org/public/english/protection/safework/worldday/products04/report04_eng.pdf.
2. Malcolm M, Wilson N, Baker M, Weistein P. Independent review of occupational injury and illness statistics [report to Labour Market Policy Group, Department of Labour]. Wellington (New Zealand): Department of Public Health, Wellington School of Medicine; 1998.
3. Steenland K, Burnett C, Lalich N, Ward E, Hurrell, J. Dying for work: the magnitude of US mortality from selected causes of death associated with occupation. Am J Ind Med 2003;43:461–82.
4. Nurminen M, Karjalainen A. Epidemiologic estimate of the proportion of fatalities related to occupational factors in Finland. Scand J Work Environ Health 2001;27(3):161–213.
5. World Health Organisation Statistical Information System (WHOSIS). Cause of death statistics: the WHO Mortality Database [database on the Internet]. World Health Organisation (WHO); 2004 [cited 2003 August]. Available from: http://www3.who.int/whosis/.
6. Blakely TA, Bates MN, Baker MG, Tobias M. Hepatitis B carriage explains the excess rate of hepatocellular carcinoma for Maori, Pacific Island and Asian people compared to Europeans in New Zealand. Int J Epidemiol 1999;28:204–10.
7. Mannetje A, Kogevinas M, Chang-Claude J, Cordier S, Gonzalez CA, Hours M, et al. Occupation and bladder cancer in European women. Cancer Causes Control 1999;10:209–17.
8. Silverman DT, Levin LI, Hoover RN. Occupational risks of bladder cancer among white women in the United States. Am J Epidemiol 1990;132:453–61.
9. Feyer AM, Langley J, Howard M, Horsburgh S, Wright C, Alsop J, et al. The work-related fatal injury study: numbers, rates and trends of work-related fatal injuries in New Zealand 1985–1994. N Z Med J 2001;114:6–10.
10. New Zealand environmental and occupational health research centre. Work-Related Fatal Traffic Injuries in New Zealand 1985–1998. Dunedin (New Zealand): New Zealand environmental and occupational health research centre, Injury prevention research unit; 2003.
11. Langley J, Feyer A-M, Wright C, Alsop J, Horsburgh S, Howard M, et al. Work-related fatal injuries in New Zealand: can a reliable electronic work-related fatality 'register' be established? J Occup Health Safety Aust N Z 2000;16:145–53.
12. Statistics New Zealand. Labour market statistics 2002. Wellington (New Zealand): Statistics New Zealand; 2003.
13. Statistics New Zealand. Injury statistics 2001/2002: work-related injuries. Wellington (New Zealand): Statistics New Zealand; 2003.
14. Leigh J, Macaskill P, Kuosma E, Mandryk J. Global burden of disease and injury due to occupational factors. Epidemiology 1999;10:626–31.
15. Karjalainen A, Kurppa K, Virtanen S, Keskinen H, Nordman H. Incidence of occupational asthma by occupation and industry in Finland. Am J Ind Med 2000;37:451–8.
16. Parkin DM, Whelan SL, Ferlay J, Raymond L, Young, J. Cancer incidence in five continents. Lyon: International Agency for Research on Cancer (IARC); 1997.
17. Leigh JP, Markowitz SB, Fahs M, Shin C, Landrigan PJ. Occupational injury and illness in the United States: estimates of costs, morbidity, and mortality. Arch Intern Med 1997;157:1557–68.
18. Work-related fatal injuries in New Zealand 1985–1994: descriptive epidemiology. Dunedin (New Zealand): University of Otago & University of Auckland; 1999.
19. Messing K, Punnett L, Bond M, Alexanderson K, Pyle J, Zahm S, et al. Be the fairest of them all: challenges and recommendations for the treatment of gender in occupational health research. Am J Ind Med 2003;43:618–29.
20. Blair A, Hoar Zahm S, Pearce NE, Heineman EF, Fraumeni JF Jr. Clues to cancer etiology from studies of farmers [review]. Scand J Work Environ Health 1992;18:209–15.
21. Checkoway H, Pearce N, Kriebel D. Research methods in occupational epidemiology. 2nd ed. New York (NY): Oxford University Press; 2004.
22. Dryson E, Walls C, McLean D, Pearce N. The OSH occupational cancer project. In: Pearce N, McLean D, Berry R, editors. Priorities in occupational health and safety. Proceedings of the Second Annual CPHR Symposium in Health Research and Policy. Wellington, New Zealand; Centre for Public Health Research; 2003. p 119–24.
23. Pearce N. Introduction. In: Pearce N, McLean D, Berry R, editors. Priorities in occupational health and safety. Proceedings of the Second Annual CPHR Symposium in Health Research and Policy. Wellington, New Zealand; Centre for Public Health Research; 2003. p 7–8.¨

Received for publication: 15 June 2004