The prevalence of heat-related cardiorespiratory symptoms: the vulnerable groups identified from the National FINRISK 2007 Study

Simo Näyhä[a, b, *], Hannu Rintamäki[b, c], Gavin Donaldson[d], Juhani Hassi[a], Pekka Jousilahti[e], Tiina Laatikainen[e, f, g], Jouni JK Jaakkola[a, h], Tiina M. Ikäheimo[a, h]

[a] Center for Environmental and Respiratory Health Research, P.O. Box 5000, FI-90014 University of Oulu, Finland

[b] Finnish Institute of Occupational Health, Oulu, Finland Aapistie 1, FI-90220 Oulu, Finland

[c] Institute of Biomedicine, P.O. Box 5000, FI-90014 University of Oulu, Finland

[d] National Heart and Lung Institute, Imperial College London, Guy Scadding Building, Royal Brompton Campus, London SW3 6LY, UK

[e] National Institute for Health and Welfare, Finland P.O. Box 30, FI-00271 Helsinki, Finland

[f] Institute of Public Health and Clinical Nutrition, University of Eastern Finland, P.O. Box 1627, FI-70211 Kuopio, Finland

[g] Hospital District of North Karelia, Tikkamäentie 16, FI-80210 Joensuu, Finland

[h] Medical Research Center Oulu, Oulu University Hospital and University of Oulu, P.O. Box 5000, FI-90014 University of Oulu, Finland

* Corresponding author:

E-mail address: simo.nayha@oulu.fi

Telephone +358-40-5646 159

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ABSTRACT

The prevalence of heat-related cardiorespiratory symptoms among vulnerable groups is not well known. We therefore estimated the prevalence of heat-related cardiorespiratory symptoms among the Finnish population and their associations with social and individual vulnerability factors. The data came from the National FINRISK 2007 Study in which 4007 men and women aged 25-74 answered questions on heat-related cardiorespiratory symptoms in the OCHQ 2007 questionnaire. Logistic regression was used to calculate odds ratios (OR), their 95% confidence intervals (CI) and model-predicted prevalence figures. The prevalence of heat-related cardiorespiratory symptoms was 12%. It increased with age, from 3% at the age of 25 years to 28% at the age of 75 years. The symptoms were associated with pre-existing lung (OR 3.93; CI 3.01-5.13) and cardiovascular disease (OR 2.27; 1.78-2.89); being a pensioner (OR 2.91; 1.65-5.28), unemployed (OR 2.82; 1.47-5.48) or working in agriculture (OR 2.27; 1.14-4.46) compared with working in industry; having only basic vs academic education (OR 1.98; 1.31-3.05); being female (OR 1.94; 1.51-2.50); being heavy vs light alcohol consumer (OR 1.89; 1.02-3.32); undertaking hard vs light physical work (OR 1.48;1.06-2.07); being inactive vs active in leisure time (OR 1.97; 1.39-2.81). The adjusted prevalence of symptoms showed a wide range of variation, from 3% to 61% depending on sex, age, professional field, education and pre-existing lung and cardiovascular disease. In conclusion, heat-related cardiorespiratory symptoms are commonly perceived among people with pre-existing lung or cardiovascular disease, agricultural workers, unemployed, pensioners and people having only basic education. This information is needed for any planning and targeting measures to reduce the burden of summer heat.

Keywords: Temperature; heat; cardiovascular; respiratory; vulnerable groups

Introduction

Climate change is the biggest global health threat of the 21st century and it will affect directly or indirectly all populations (Haines et al. 2009). The primary health impacts are mediated through changes in weather, in particular by heat waves and changes in ambient temperatures. The direct effects of temperature such as heat-related mortality are likely to increase as temperatures rise towards the end of the 21st century, although the effects on overall mortality would be offset by adaptation of population (Donaldson et al. 2003a, Christidis et al. 2010) and lowering of winter mortality (Keatinge et al. 2000) even though this is contested (Staddon et al. 2014). Heat-related health hazards are particularly likely in northern areas where temperature is predicted to rise most (IPCC Fifth Assessment Report 2013).

Deaths from cardiovascular, respiratory and all causes increase not only during identified heat waves (Näyhä 1981; Hajat et al. 2006; Martiello and Giacci 2010; Kollanus and Lanki 2014, Lee et al. 2016, Zhang et al. 2016) but also during a normal summer if temperature exceeds the optimal temperature for the area (Näyhä 2007; Hajat and Kosatsky 2010; Guo et al. 2013). Comparable increases are seen in hospital admissions due to cardiovascular (Semenza et al. 1999; Morabito et al. 2005) and respiratory diseases (Michelozzi et al. 2009). The vulnerable population groups include the elderly, people suffering from debilitating medical conditions, women, and the socially deprived and disadvantaged ones (Basu 2009; Hajat et al. 2010, Stafoggia et al. 2006). People living alone (Semenza et al. 1996), in isolation (Hajat et al. 2010) or in institutions and those unable to care for themselves (Bouchama et al. 2007) are adversely affected by summer heat. Physical exertion, either occupational (Fleischer et al. 2013) or leisure-time related (Centers for Disease Control and Prevention 2011) conveys an extra risk, as does inactivity due to confinement to bed (Semenza et al. 1996; Bouchama et al. 2007; Martiello and Giacchi 2010). People living in colder parts of the world may be more susceptible to the effects of heat stress than those living in warmer areas because they are less physiologically adjusted and have less environmental protection (Keatinge et al. 2000; Guo et al. 2013). Finally, also other co-morbid conditions such as obesity (Vandentorren et al. 2006) and alcoholism (Kilbourne et al. 1982) will further increase the hazards of heat exposure.

Most studies on heat-related adverse effects among the general population are limited to mortality and hospital admissions. However, deaths and acute episodes of disease only constitute a fraction of the entire spectrum of heat-related harms, and a comprehensive assessment should include subjective symptoms which may forecast more severe events (Josseran et al. 2010). Unlike other environmental hazards, heat-related symptoms are easily perceived and enable people to avoid the heat exposure, before any disease attacks occur (Gronlund 2014). However, only one small study has reported heat-related symptoms (e.g. shortness of breath) in the general population during a severe heat-wave in Australia (Nitschke et al. 2013). In fact, the vast majority of people in the northern climate suffer from heat-related complaints even during a normal summer, with most of them being the elderly or women (Näyhä et al. 2014). As summer temperatures are predicted to rise and heat waves to occur more frequently and with higher intensity (IPCC Fifth Assessment Report 2014), a higher occurrence of heat-related adverse effects can be expected. It is therefore prudent to 1) identify the groups most at risk and 2) estimate the prevalence of complaints within these groups. Our previous study asking about heat-related symptoms in the National FINRISK 2007 Study focused on sex and age effects in 28 symptoms and complaints among the Finnish population but did not look for other vulnerable groups (Näyhä et al. 2014). The present paper using the same database determines the prevalence of heat-related cardiorespiratory symptoms in population subgroups classified according to a number of social, occupational and health characteristics. We selected cardiorespiratory symptoms for study, because they can be meaningfully linked with cardiovascular and respiratory events which constitute the major part of heat-related mortality (Kilbourne 1999). Identification of subgroups at special risk could reduce the costs by targeting advice and intervention.

Material and methods

The area studied

Finland is a subarctic Northern European country with cold winters and cool, short summers. The study areas were South (the cities Turku and Loimaa with nine adjoining rural municipalities, and the cities of Helsinki and Vantaa), East (the counties of North Savo and North Karelia) and North (the province of Oulu), as shown in Figure 1. In the South, the population is mainly urban and the climate maritime while in other areas, the population is more rural and the climate more continental. In 1981-2010, the mean temperature in July (the warmest month) ranged from +18 °C in the South (Helsinki) to +16 °C in the North (Oulu). In summer 2006, i.e. the summer preceding the present survey, the temperatures exceeded the long-term average by 1-2 °C in the areas studied, and the number of hot days (highest daily temperature ≥ 25 °C) compared with that in the reference period 1981-2010 was greater in the South (13 vs 1) but not in the North (8 vs 9).

Study population

The National FINRISK Study is a series of nationwide surveys conducted in Finland since 1972 at 5-year intervals with the aim of monitoring the risk factors for chronic diseases. The participants of the present study consisted of a sub-sample of the FINRISK 2007 study conducted in January-March. A random sample of 2000 people aged 25-74 years, stratified by sex and 10-year age groups, was drawn in each of the five study areas. The entire sample comprised 9957 people of which two thirds were invited to participate in a more detailed study on temperature-related symptoms and one third underwent a dietary survey (they did not participate in the cold-heat study). Out of all 9957 subjects, 6733 (68%) participated in the main study, and 4193 subjects belonging to the temperature sub-sample attended at the clinic and were given the Oulu Cold and Heat Questionnaire (OCHQ 2007) which they were asked to return in a pre-paid envelope. The response rates in the temperature sub-sample and dietary survey were similar (63% and 62%, respectively). The questionnaire was returned by 4007 subjects and linked with the FINRISK study data. The details of the study protocol are reported elsewhere (Vartiainen et al. 2010). The study protocol was reviewed and approved by Coordinating Ethics Committee of the Helsinki and Uusimaa Hospital District. All participants gave a written informed consent.

The questionnaires

The OCHQ 2007 asked about symptoms and complaints experienced in warm and hot weather (the English translation of the questionnaire is given elsewhere (Näyhä et al. 2014)). The questionnaire was designed by the study team at Kastelli Research Center, Oulu, which comprised specialists in thermophysiology, cardiology, chest medicine, physiatrics, epidemiology, occupational medicine and public health science. The questions were designed based on the experience gained in previous FINRISK studies (Raatikka et al. 2007; Ikäheimo et al. 2014). The heat-related cardiorespiratory symptoms were elicited by asking the respondents to tick “yes” or “no” to whether “Does warm weather cause you to have any of the following symptoms?”: shortness of breath; prolonged cough or coughing bouts; wheezing of breath; increased excretion of mucus from the lungs; chest pain; cardiac arrhythmias. As many of the symptoms may overlap, a composite variable denoted as cardiorespiratory symptoms was created as follows: if the respondent had experienced at least one of these six individual symptoms, the outcome was coded as 1, otherwise 0.

In the main FINRISK questionnaire, the participants were asked about diagnosed medical conditions, education, professional field, marital status, physical workload, leisure-time physical activity (Hu et al. 2003), smoking, and the usual quantity and frequency of beer, wine and spirits consumed during the past 12 months (Sundell et al. 2008). Body height and weight were measured at the survey site (to an accuracy of one millimetre and 100 grams, respectively) and converted to body mass index (BMI; kg/m^2). Information on sex, age and place of residence was available from the Finnish National Population Register Centre. The definitions and classification of the variables are shown in Table 1.

Data analysis

The proportion of respondents who reported having experienced cardiorespiratory symptoms during warm weather was treated as the prevalence of individuals having such a tendency. Logistic regression was used to assess the relationship between heat-related cardiorespiratory symptoms (yes/no) and demographic and individual factors, one factor at a time, but adjusting for sex and age. A fully adjusted model was then fitted including all the variables. To allow for curvilinear age trends, age (in one-year classes) was smoothed by natural cubic splines with 3 degrees of freedom. The results were first expressed as odds ratios (OR) with their 95% confidence intervals (CI). The ORs express the relative odds for having cardiorespiratory symptoms in each class compared with a reference class. To have the actual prevalence for all classes of the explanatory factors, we calculated marginal predictions from the adjusted logistic regressions conditioned at mean values of all other factors in the model (Lane and Nelder 1982; Graubard and Korn 1999) (details are in Appendix). The adjusted prevalence in a given category then expresses the model-predicted prevalence of cardiorespiratory symptoms in a stereotypic individual having average values of all factors in the model. Adjusted prevalences were also calculated according to age, letting age vary from 25 to 74 years, and also at fixed values of professional and educational groups and pre-existing diseases. Compared with ORs, the model-adjusted predictions illustrate better the scale of the group differences. The calculations were performed using the R software, release 3.01 (R Development Core Team 2012).

Results

Characteristics of subjects

The mean age of the subjects was 51.1 years (men 51.8, women 50.5). 46% of the subjects were men, 72% were married or cohabiting, 15% had academic education, 45% were engaged in office work or services, 11% in industry and 3% in agriculture or related work and 41% were economically inactive (students, housewives, pensioners or unemployed). A physician diagnosed cardiovascular disease was reported by 1111 subjects (28%), and of these, 953 (86%) had arterial hypertension and 201 (18%) coronary heart disease. A diagnosed lung disease was reported by 417 subjects (11%), 374 (90%) of these having bronchial asthma and 71 (17%) chronic bronchitis or emphysema. Further details on subject characteristics are in Table 1.

Crude prevalence of heat-related cardiorespiratory symptoms

Out of all 3811 subjects who answered any of the six questions on heat-related cardiorespiratory symptoms, 469 (12%) reported at least one symptom (9% of men, 15% of women). Cardiac arrhythmia was reported by 6% (4% of men versus 9% of women), chest pain by 2% (2% vs 2%), dyspnoea by 5% (3% vs 7%), cough by 2% (1% vs 2%), wheezing by 2% (2% vs 2%) and mucus production by 3% (3% vs 3%).

Figure 2 shows the age trend in the prevalence of all heat-related cardiorespiratory symptoms in the form of smoothed splines. Between the ages 25 to 74 years, the prevalence increased from 3 to 28% (2 to 24% in men, 4 to 32% in women), but among subjects having a pre-existing cardiovascular disease, the prevalence was higher throughout the age range (from 8 to 31%), and still higher among those having a lung disease (12 to 56%). Women had a higher prevalence than men, especially at older ages.

The crude prevalence of cardiorespiratory symptoms also varied depending on a number of other factors, from 6 to 34% (Table 2). The prevalence was particularly high among pensioners, the unemployed and agricultural workers, with 3.8-fold, 3.0-fold and 3.0-fold excesses, respectively, compared with participants engaged in industry. Having only a basic education was associated with a 3.1-fold prevalence compared with having an academic education. The subjects who were physically inactive during leisure-time, showed a 2.8-fold higher prevalence than the active ones, but physical workload was not associated with the symptoms. The prevalence of symptoms increased with increasing body mass index, reaching a 2-fold excess among the severely obese (BMI ($\geq$ 35 kg/m^2) compared with normal weight individuals (BMI (< 25 kg/m^2), and the prevalence was relatively high among women, heavy alcohol consumers, current smokers, those residing in the North or East and the divorced or widowed ones.

A pre-existing cardiovascular disease was associated with a 2.8-fold prevalence compared with those having no such disease (23% vs 8%), and a subgroup analysis showed a higher prevalence ratio separately for coronary heart disease (4.0; 44% vs 11%) and a lower one (2.0; 20% vs 10%) for arterial hypertension. The subjects having a pre-existing lung disease showed a 3.4-fold prevalence compared with those having no such disease (34% vs 10%), with somewhat different prevalence ratios separately for bronchial asthma (3.2; 32 % vs 10%) and chronic bronchitis (4.2; 50% vs 12%). These specific conditions were grouped into cardiovascular and respiratory disease groups for further analyses.

Adjusted analyses

Most variations in the crude prevalence were repeated in the sex- and age-adjusted analyses (Table 2), and further adjustments for all other variables caused only minor changes. The ORs for region of residence and smoking reduced to insignificance as did those for BMI, mainly due to inclusion of cardiovascular and lung disease to the model. However, being engaged in heavy physical work now showed elevated odds for having the symptoms.

The right-hand column of Table 2 translates the full adjusted model to adjusted prevalence figures in each subgroup assuming average values of all other explanatory factors. The adjustment reduced some of the high prevalence figures, mostly to less than 20%, notably among pensioners, the divorced/widowed ones and subjects having only basic education.

However, the estimated combined effects of two or more factors were much larger. This is illustrated in Figure 3 in form of model-predicted age patterns in the prevalence of cardiorespiratory symptoms, stratifying by sex, cardiovascular and lung disease, professional field and educational level. First, the rising overall age trend was greatly reduced compared with the unadjusted trends. At the age of 74 years, for example, the adjusted prevalence of symptoms among all participants was only 7% and 12% among men and women, respectively, while the unadjusted prevalences in Figure 2 were 24% and 32%, respectively. Thus, only about a third of the symptom prevalence (7% / 24% in men; 12% / 32% in women) could be attributed to age alone.

Wide variations in prevalence still existed when stratifications were made by disease and professional field (Figure 3A). Among men and women aged 50 years, for example, who had a cardiovascular and lung disease, the prevalence of symptoms reached 34% and 50%, respectively, and varied from 21 to 61% depending on professional field. Figure 3B shows the respective prevalence estimates by educational level, with variations from 27 to 59% at the age of 50 years, depending on educational class. Figure 3 also illustrates the female excess in the estimated prevalence. Thus at the age of 50 years, for example, the prevalence of cardiorespiratory symptoms among women and men who worked in industry and had no cardiovascular or lung disease, was 6% and 3%, respectively, i.e. a difference of 3%, while the respective figures among pensioners who had a cardiovascular and lung disease, were 61% and 45% - a difference of 16%. The respective sex differences were similar between respondents with academic vs basic education.

Discussion

Summary of findings

The present survey is the first one to identify and describe quantitatively the large spectrum of vulnerability factors which underlie heat-related cardiorespiratory symptoms. During a normal summer, only a moderate proportion (12%) of people aged 25 to 74 years in this northern population suffer from heat-related cardiorespiratory symptoms, but the prevalence can exceed 60% in specific groups with either one or multiple risk factors such as pre-existing cardiorespiratory diseases or poor social status. Identification of these groups will help us to target pre-emptive measures appropriately not only during heat waves proper (IPCC Fifth Assessment Report 2014) but also during a normal summer (Basu 2009, Hajat et al. 2006).

Factors underlying heat-related cardiorespiratory symptoms

Heat-related mortality and morbidity increase by age (e.g. Basu 2009, Michelozzi et al. 2009). We have previously shown that a wide range of heat-related symptoms and complaints also increase with age (Näyhä et al. 2014). However, the present results show that the high prevalence of such symptoms among the aged is mainly attributable to factors other than age. At the age of 74 years, for example, only about a third of the symptom prevalence could be attributed to age alone, the rest being due to cardiorespiratory morbidity and unfavourable personal characteristics such as overweight, excessive alcohol consumption or being divorced or widowed. The effect of age is explained by age-related deterioration of thermoregulation, involving both physiological and behavioral changes (Stapleton et al. 2014), declining sweat output, diminished vasodilatation, lower skin blood flow and reduced cardiac output, diminished awareness of heat, lowered sensation of thirst (Kenny et al. 2010), as well as reduced mobility and cognition (Hansen et al. 2011).

Patients suffering from cardiovascular or lung diseases have an elevated risk for dying or being admitted to hospital during hot periods (Hajat et al. 2010), and we noted a high prevalence of heat-related cardiorespiratory symptoms among participants having such conditions. The body's response to heat stress involves peripheral vasodilatation to shunt blood to the skin where heat can be lost by conduction. The resulting decrease in blood pressure due to the vasodilatation needs to be compensated with increased cardiac output, and people with any disease that impairs the ability to increase heart rate or stroke volume would be under increased cardiovascular strain. Furthermore, sweating to lose heat by evaporation imposes further stress on the heart through dehydration (Kenny et al. 2010). Dehydration decreases plasma volume and increases red blood cell concentration and blood viscosity making it harder to circulate. Heat stress also causes the release of additional platelets into the circulation. These changes in blood properties may lead to an increased risk for coronary events (Donaldson et al. 2003b). Finally, an additional risk is conveyed by the medications some of these patients use, e.g. diuretics, beta-blockers and anticholinergics (Stöllberger et al. 2009) which impair thermoregulation. Although the present study focused on the disease groups accounting for a majority of heat-related morbidity and mortality, we recognize that also other conditions, such as metabolic (e.g. diabetes), renal, neural, or psychiatric diseases may be aggravated with heat exposure (Hajat et al. 2010).

We observed a substantially higher prevalence of cardiorespiratory symptoms among women than men. This is understandable in terms of women having a higher surface-to-mass ratio, greater subcutaneous fat thickness (Seidell et al. 1988) and lower sweat production rate (Dehghan et al. 2013). Women also have higher heat mortality (Basu 2009, IPCC Fifth Assessment Report 2014, Stafoggia et al. 2006). While consistent, the finding must be taken with caution, since women tend to report more health-related symptoms than men (Barsky et al. 2001).

The prevalence of heat-related cardiorespiratory symptoms increased consistently with lowering education and was high among pensioners, the unemployed and participants engaged in agriculture. This is in line with studies reporting high heat mortality in low educational and poor socioeconomic groups (Vandentorren et al. 2006; Gronlund 2014). Agricultural workers frequently suffer from heat-related symptoms (Mirabelli et al. 2010; Kravchenko et al. 2013) and have high heat mortality (Gronlund 2014; Xiang et al. 2014). In our sample, hard physical work was associated with heat-related cardiorespiratory symptoms but leisure-time physical activity was not, inactive persons showing the highest prevalence. This could result from an over-representation in the inactive group of sick individuals who describe themselves as immobile because of ambulatory or motivational problems.

Earlier studies have shown that people living alone have higher heat mortality than others (Semenza et al. 1996; Bouchama et al. 2007), as have single, widowed and divorced individuals (Stafoggia et al. 2006). We did observe a relatively high prevalence of heat-related cardiorespiratory symptoms among the divorced or widowed but not among the single ones. One might speculate that people who have been left alone after marriage are less able to care for themselves.

There are several comorbid or behavioral conditions that may account for increased heat-related health risks. Our findings are in line with studies reporting an elevated risk of heat hazards among obese individuals (Vandentorren et al. 2006). As we failed to confirm an independent association of obesity with heat-related cardiorespiratory symptoms, the finding could have been confounded by the cardio-respiratory diseases that obese individuals are more likely to suffer. Heavy consumption of alcohol diminishes the contractibility of the heart, lowers blood pressure and may lead to dehydration (Hajat et al. 2010). Our finding of a high prevalence of heat-related cardiorespiratory symptoms among the heavy alcohol consumers suggests that the risk may be limited to a small population segment. Smoking could be entertained as a risk factor for heat hazards as it worsens endothelial function and reduces the capacity of the skin vessels to dilate (Avery et al. 2009), but we did not observe any independent association of smoking with the symptoms with any certainty.

We also noted a higher prevalence of heat-related cardiorespiratory symptoms in northern than in southern Finland, which could be expected from studies reporting that heat-related mortality is higher (Keatinge et al. 2000) and the threshold temperature for heat mortality lower (Hajat and Kosatsky 2010; Guo et al. 2013) in northern than southern areas. However, our adjusted analyses could not confirm the initial finding.

Strengths

The strength of our study is the large, representative population living in a cold climate where people are known to be more vulnerable to heat hazards than those living in a warmer climate (Keatinge et al. 2000; Guo et al. 2013). We had information on most personal and demographic characteristics increasing individual's vulnerability, such as low education which is a known risk factor for poor health (IPCC Fifth Assessment Report 2014). We focused on heat-related cardiorespiratory symptoms which can be meaningfully interpreted as antecedents of severe cardiorespiratory events. The use of 1-year age classes and the flexible smoothing method allowing for curvilinear trends allowed us to determine the prevalence of symptoms at the highest ages where they most likely occur. We also presented adjusted prevalence figures which are more informative at the population scale than ORs alone. Since our findings pertain primarily to normal summer heat rather than heat waves proper, they have particular relevance in the northern climate where extremely hot periods are rare. Only an estimated 20 to 50% of all heat-related mortality is attributable to identified heat-waves (Hajat et al. 2006).

Limitations

While the validity of the questions on heat-related cardiorespiratory symptoms would seem adequate, individual differences in threshold temperature at which symptoms become manifest may have caused an unknown bias to the prevalence figures. It is also possible that the respondent's expectations of what (s)he should answer may have affected the results. We recognize that we focused on symptoms, not on actual health effects, and it remains unclear how well heat-related symptoms predict future morbidity and mortality. However, the outcome variable was composed of six separate questions on individual symptoms which can be meaningfully linked with future cardiac and respiratory events. A composite variable was regarded as better than single questions, since in patients' mind, the symptoms partly overlap. One limitation is that medications some subjects may have used were not taken into account. Use of *pro re nata* prescriptions such as nitroglycerin would lead to under-estimation of the effects we describe. The response rate was satisfactory, but some unknown bias due to selective participation remains a possibility.

Practical inmplications

The results of our study aids in early recognition of vulnerable groups for heat exposure. This is important as the most obvious strategy to prevent any heat harms is to target preventive measures to those at risk (Bouchama et al. 2007). Since these symptoms often occur before any actual disease attacks, the mass media should warn high-risk individuals some days before any significant heat waves (Diaz et al. 2006), and according to British experience, giving personal warnings by telephone may be useful (Bhaskaran et al. 2011). Pre-emptive measures include seeking shelter in cool premises, adequate fluid intake, light clothing, taking cool showers and avoiding excessive physical exercise in work and leisure time and avoiding excessive alcohol consumption. People with cardiovascular or lung conditions should ask their doctors if their medication was to be adjusted.

Conclusions

We have identified a number of population subgroups with a high prevalence of heat-related cardiorespiratory symptoms. These are commonly perceived among people with pre-existing lung or cardiovascular disease, agricultural workers, unemployed, pensioners and people having only basic education. Timely public health and individual measures taking into account individual susceptibility may improve adaptation to higher temperatures and prevent large loss of life during the warm season.

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Table 1. Subjects classified according to demographic and personal characteristics. The National FINRISK 2007 Study

Characteristic	Classification	No.	(%)	Men (%)
Sex	Men	1860	(46.4)	
	Women	2147	(53.6)	
	All	4007	(100.0)	
Age	25–34	630	(15.7)	42.2
	35–44	734	(18.3)	45.4
	45–54	840	(21.0)	45.7
	55–64	899	(22.4)	47.6
	65–74	904	(22.6)	49.7
	All	4007	(100.0)	46.4
Region [a]	South	1542	(38.5)	45.2
	East	1636	(40.8)	47.0
	North	829	(20.7)	47.5
	All	4007	(100.0)	46.4
Marital status	Married/cohabiting	2892	(72.3)	48.9
	Divorced/widowed	573	(14.3)	31.4
	Single	535	(13.4)	49.0
	All	4000	(100.0)	46.4
Education	Academic	598	(15.0)	41.6
	College/polytechnic	1046	(26.3)	42.3
	High school/vocational	1318	(33.1)	49.5
	Basic	1021	(25.6)	49.9
	All	3983	(100.0)	46.5
Professional field [b]	Industry	429	(10.8)	86.2
	Office	1765	(44.6)	37.7
	Agriculture	136	(3.4)	61.8
	Pensioner	1159	(29.3)	48.8
	Unemployed	210	(5.3)	44.3
	Others	259	(6.5)	22.8
	All	3958	(100.0)	46.4

Physical load	Light	2194	(55.1)	44.4
at work[c]	Moderate	932	(23.4)	39.4
	Heavy/very heavy	856	(21.5)	59.2
	All	3982	(100.0)	46.4
Physical activity	Active/very active	1043	(26.1)	49.2
in leisure-time	Moderate	2140	(53.6)	44.7
	Inactive	810	(20.3)	47.4
	All	3993	(100.0)	46.4
Body mass index	Normal (< 25.0)	1480	(36.9)	36.5
(kg/m^2)	Overweight (25.0–29.9)	1623	(40.5)	56.6
	Obese (30.0–34.9)	640	(16.0)	49.1
	Severely obese (≥ 35.0)	264	(6.6)	33.0
	All	4007	(100.0)	46.4
Smoking[d]	Never smoker	2164	(54.2)	36.4
	Ex-smoker	1035	(25.9)	60.3
	Current smoker	790	(19.8)	55.3
	All	3989	(100.0)	46.4
Alcohol	Light	3732	(93.7)	44.9
consumption[e]	Moderate	150	(3.8)	72.7
	Heavy	100	(2.5)	61.0
	All	3982	(100.0)	46.4
Cardiovascular disease[f]	No	2848	(71.9)	44.7
	Yes	1111	(28.1)	50.3
	All	3959	(100.0)	46.3
Lung disease[g]	No	3534	(89.4)	47.2
	Yes	417	(10.6)	36.9
	All	3951	(100.0)	46.1
All participants		4007		46.4

[a] South: the cities of Helsinki, Vantaa, Turku and Loimaa, and 9 municipalities adjoining the latter two; East: the counties of North Savo and North Karelia; North: the province of Oulu

[b] Industry: factory work, mining, construction work or related occupations; Office: office, services, mental work (planning, management, administration or related occupations);

Agriculture: farming, forestry, stock raising; Others: students and housewives

[c] Light: light sedentary work; Moderate: moderately heavy work including walking but not carrying objects; Heavy/very heavy: heavy work including frequent walking and lifting objects, climbing stairs or uphill (e.g., carpenter, work in engineering workshops) and very heavy physical work including lifting and carrying heavy objects, or physical loads on the trunk and extremities (e.g., heavy agriculture and forestry work, heavy construction or industrial work)

[d] Current smoker: smoked regularly for at least one year and had smoked during the previous month; Ex-smoker: (previously smoked regularly but quit at least one month before the survey)

[e] Among men: Light: 0–230 grams/week; Moderate 230–349 grams/week; Heavy: ≥ 350 grams/week. Among women: Light: 0–150 grams/week; Moderate 150–209 grams/week; Heavy: ≥ 210 grams/week

[f] Self-reported physician-diagnosed angina pectoris, arterial hypertension or cardiac insufficiency during the past 12 months, or past myocardial infarction, bypass surgery, angioplasty or cerebral stroke

[g] Self-reported physician-diagnosed bronchial asthma, chronic bronchitis or emphysema during the past 12 months, or bronchial asthma diagnosed at some time

Table 2 Prevalence of heat-related cardiorespiratory symptoms[a] and odds ratios (OR) from adjusted logistic regressions, together with their 95% confidence intervals (CI) . The National FINRISK 2007 Study.

	Crude prevalence	Logistic model adjusted for sex and age[b]		Logistic model adjusted for all factors[c]		Adjusted prevalence[d]	
	(%)	OR	(95% CI)	OR	(95% CI)	%	(95% CI)
Sex							
Men	8.8	1.00		1.00		7.8	(6.0–9.6)
Women	15.3	1.99	(1.62–2.46)	1.94	(1.51–2.50)	14.1	(11.5–16.7)
Region							
South	10.7	1.00		1.00		10.2	(7.9–12.5)
East	13.4	1.32	(1.06–1.66)	1.14	(0.89–1.46)	11.5	(9.1–13.8)
North	13.2	1.29	(0.98–1.69)	1.05	(0.77–1.42)	10.6	(7.9–13.4)
Marital status,							
Married/cohabiting	11.4	1.00		1.00		10.3	(8.4–12.2)
Divorced/widowed	20.1	1.36	(1.05–1.75)	1.39	(1.05–1.83)	13.8	(10.2–17.4)
Single	9.2	1.06	(0.75–1.47)	1.02	(0.70–1.45)	10.5	(7.0–14.0)
Education							
Academic	6.8	1.00		1.00		7.9	(5.1–10.7)
College/polytechnic	8.6	1.29	(0.88–1.93)	1.12	(0.74–1.73)	8.8	(6.6 –11.0)
High school/vocational	11.5	1.83	(1.28–2.68)	1.52	(1.02–2.32)	11.5	(9.0–14.1)
Basic	20.9	2.58	(1.80–3.80)	1.98	(1.31–3.05)	14.5	(11.1–17.9)
Professional field							
Industry	5.6	1.00		1.00		6.0	(3.2–8.8)
Office	8.4	1.09	(0.70–1.79)	1.63	(0.98–2.81)	9.4	(7.5–11.4)
Agriculture	16.9	2.63	(1.39–4.96)	2.27	(1.14–4.46)	12.6	(6.4–18.9)
Pensioner	21.4	2.47	(1.48–4.25)	2.91	(1.65–5.28)	15.7	(10.8–20.5)
Unemployed	16.9	2.43	(1.38–4.37)	2.82	(1.47–5.48)	15.3	(9.5–21.0)
Others	6.7	1.22	(0.60–2.40)	1.47	(0.68–3.12)	8.6	(3.8–13.4)
Physical load at work							
Light	13.9	1.00		1.00		10.0	(7.8–12.1)
Moderate	9.2	0.81	(0.62–1.06)	1.03	(0.75–1.40)	10.2	(7.4–13.0)

Heavy/very heavy	11.4	1.19	(0.91–1.55)	1.48	(1.06–2.07)	14.1	(10.5–17.7)
Physical activity in leisure time							
Active/very active	6.5	1.00		1.00		8.2	(5.9–10.5)
Moderate	13.1	1.66	(1.25–2.23)	1.37	(1.01–1.88)	10.9	(8.7–13.0)
Inactive	17.9	2.72	(1.99–3.76)	1.97	(1.39–2.81)	14.9	(11.5–18.4)
Body mass index (kg/m^2)							
Normal (< 25.0)	9.8	1.00		1.00		11.3	(8.8–13.9)
Overweight (25.0–29.9)	12.0	1.09	(0.85–1.39)	0.94	(0.72–1.23)	10.7	(8.5–13.0)
Obese (30.0–34.9)	14.9	1.26	(0.93–1.69)	0.81	(0.57–1.12)	9.3	(6.7–12.0)
Severely obese (≥ 35.0)	22.5	2.02	(1.40– 2.87)	1.07	(0.71–1.59)	12.0	(7.9–16.1)
Smoking							
Never	12.5	1.00		1.00		10.8	(8.6–13.0)
Ex-smoker	12.7	1.16	(0.91–1.48)	1.06	(0.81–1.38)	11.3	(8.6–14.0)
Current smoker	11.2	1.29	(0.97–1.69)	0.94	(0.69–1.28)	10.2	(7.5–12.9)
Alcohol consumption							
Light	12.2	1.00		1.00		10.8	(8.8–12.7)
Moderate	7.6	0.76	(0.38–1.37)	0.74	(0.36–1.37)	8.1	(3.2–13.1)
Heavy	19.6	2.06	(1.19–3.42)	1.89	(1.02–3.32)	18.5	(9.7–27.4)
Cardiovascular disease							
No	8.2	1.00		1.00		8.8	(7.1–10.5)
Yes	23.0	2.61	(2.10–3.26)	2.27	(1.78–2.89)	17.9	(14.2–21.6)
Lung disease							
No	9.9	1.00		1.00		9.5	(7.8–11.2)
Yes	33.5	4.21	(3.28–5.38)	3.93	(3.01–5.13)	29.2	(23.1–35.2)

[a] Heat-related shortness of breath, prolonged cough/cough bouts, wheezing of breath or increased excretion of mucus from the lungs, chest pain, cardiac arrhythmia

[b] Adjusted for natural cubic spline of age with 3 degrees of freedom; sex adjusted only for age

[c] Adjusted for all variables in this table (N=3631)

[d] Marginal predictions from the fully adjusted model, calculated at means of all explanatory factors

Figure captions

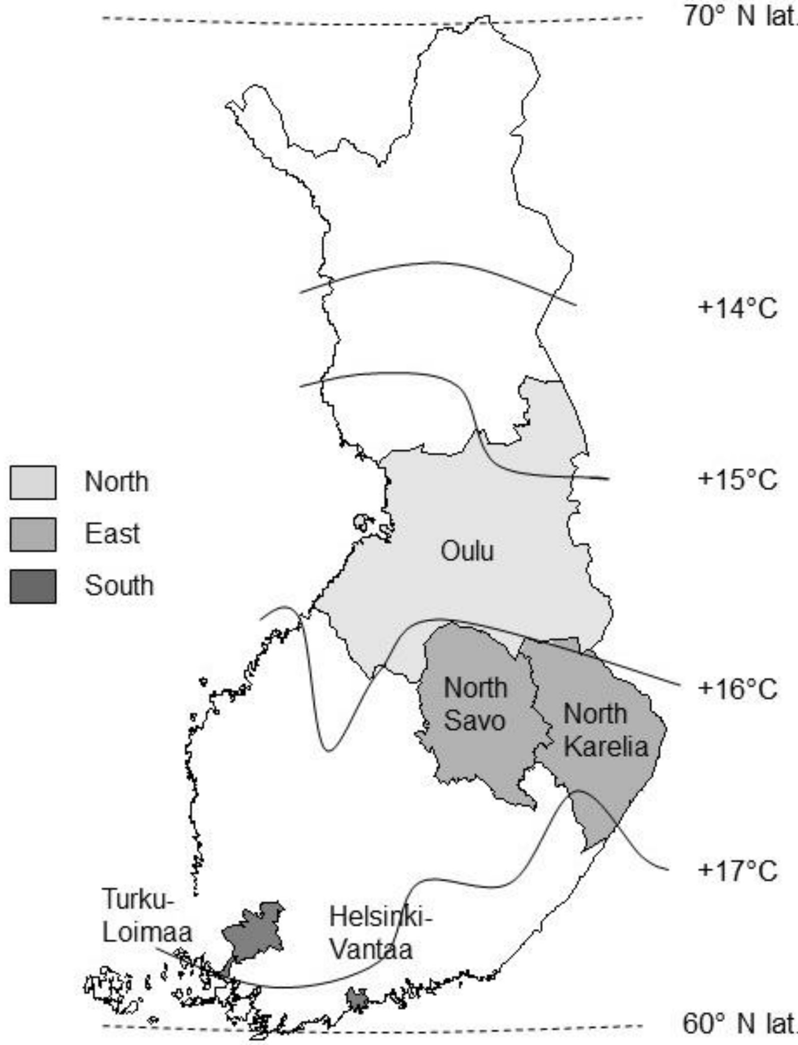

Fig. 1 The areas of the FINRISK 2007 cold-heat sub-study. Isotherms are mean July temperatures, 1981-2010.

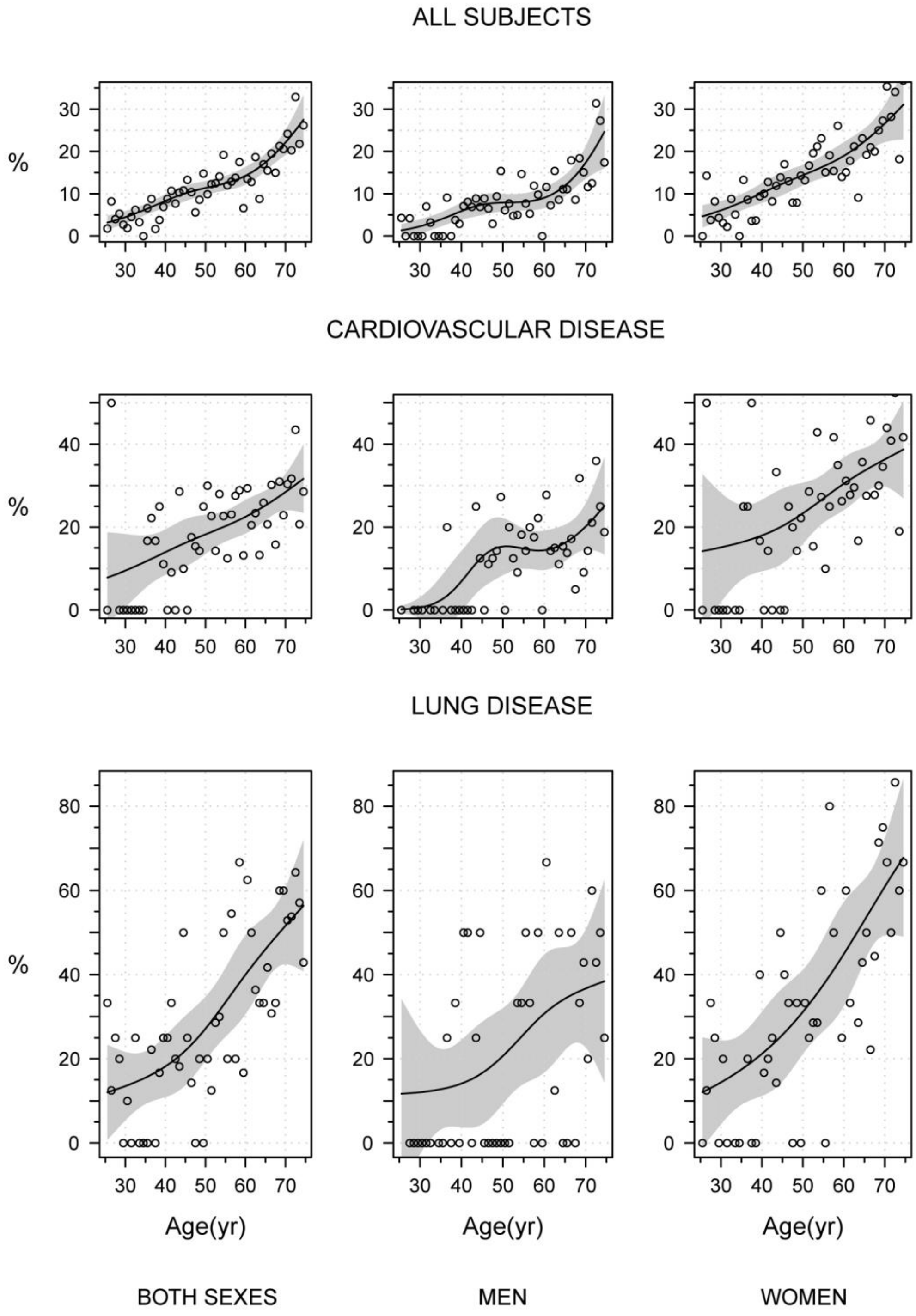

Fig. 2 Prevalence of heat-related cardiorespiratory symptoms among all subjects and those having a diagnosed cardiovascular or lung disease. Circles are empirical prevalences in each 1-year age interval. Continuous line shows the prevalence smoothed by natural cubic spline with 3 degrees of freedom and shaded area is its 95% confidence band.

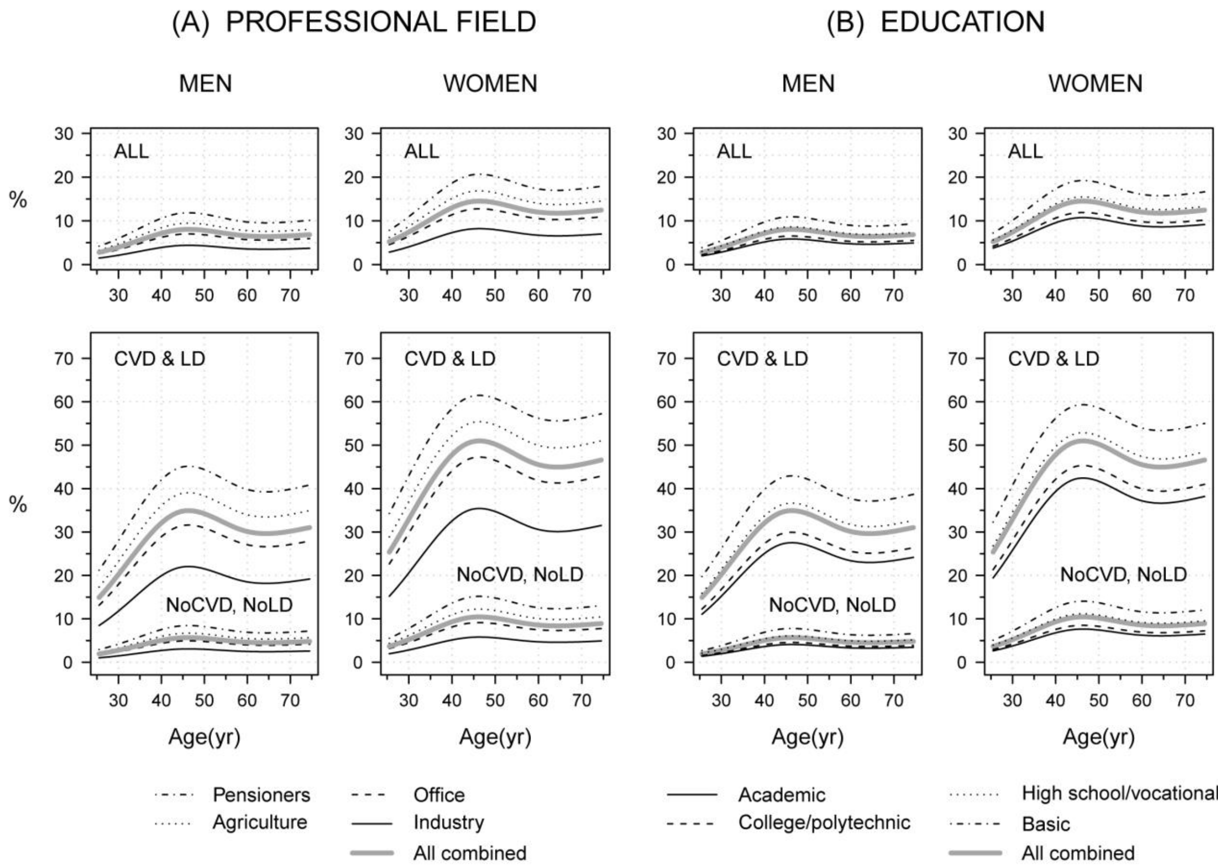

Fig. 3 Model-adjusted prevalence of heat-related cardiorespiratory symptoms by age, separately for all subjects (ALL), those having a pre-existing cardiovascular (CVD) and lung disease (LD) and those having no such diseases (NoCVD, NoLD), separately for four professional fields and educational classes.

APPENDIX

##
MODEL-BASED ADJUSTED PREVALENCE
##

Variables

Abreviation	Explanation	Coding (0 = no, 1 = yes)
y	Outcome variable	Presence of cold-related cardiorespiratory symptoms (0,1)
Age	Age	1-year classes
Sex	Sex	Male (0,1)
		Female (0,1)
Reg	Region of residence	South (0,1)
		East(0,1)
		North (0,1)
Marital	Marital status	Married (0,1)
		Divorced/Widowed (0,1)
		Single (0,1)
Edu	Education	Academic (0,1)
		College/polytechnic (0,1)
		Vocational school (0,1)
		Basic education (0,1)
Prof	Professional field	Industry (0,1)
		Office (0,1)
		Agriculture (0,1)
		Pensioner (0,1)
		Unemployed (0,1)
		Other (0,1)
Wload	Physical load at work	Light (0,1)
		Moderate (0,1)
		Heavy (0,1)
PA	Physical activity in leisure time	Active (0,1)
		Moderate (0,1)
		Inactive (0,1)
BMI	Body mass index	Normal (0,1)
		Overweight (0,1)
		Obese (0,1)
		Severely obese (0,1)
Smo	Smoking	Never smoked (0,1)
		Ex-smoker (0,1)
		Current daily smoker (0,1)
CVD	Cardiovascular disease	(0,1)
RES	Lung disease	(0,1)

Rationale

1) All explanatory variables except age were coded as (0,1), decomposing multi-class variables to separate classes (0,1). Age was treated as continuous, to an accuracy of one year.
2) A generalized linear model was fitted using a binary outcome (presence of cold-related symptoms), binomial error distribution and logistic link function. All explanatory variables mentioned above were included. Age was smoothed by a natural cubic spline with knots at 44 and 59 years (tertile cutpoints), all other explanatory variables being treated as (0,1).
3) Means of all binary explanatory factors were calculated.
4) The prevalence figures adjusted to all model factors were calculated by extracting the model-predicted probability of the outcome y at the age of 50 years (approximate mean age of the respondents) and at means of all other explanatory factors. This figure represents the prevalence of cold-related symptoms in an "average" individual adjusted to all factors in the model.
5) The age-specific prevalence (Figure 3) was calculated in a similar way as above but setting age to years 25, 26, …,74. This represents the prevalence of cold-related symptoms at each age, adjusted to all factors other than age.

R code (sample)

```
# Model fitting

mod <- glm( y ~ ns(Age + 0.5, knots=(c(44,59)+0.5),Boundary.knots=range(25,74)) +
                Female +
                East + North +
                DivorWid + Single + College + Vocation + Basic +
                Office + Agricul + Pension + Unempl + Other +
                WModer + WHeavy +
                PA.Moder + PA.Inact +
                BMIover + BMIobese + BMIveryo + SmoEx + SmoDai +
                AModer + AHeavy +
                CVD + RES,
                family=binomial(link="logit") )

# Regression coefficients

round(cbind( exp(coef(mod)),exp(confint(mod))),3)


# Means of explanatory variables (other than age) at which the model predictions
# were calculated

#-------------
# Sex
#-------------

mea.Male    <- mean(Female); mea.Male
mea.Female  <- mean(Female); mea.Female

#----------------
# Reg
#-----------------

mea.South    <- mean(South); mea.South
mea.Centr    <- mean(Centr); mea.Centr
mea.North    <- mean(North); mea.North


#----------------
```

```
# Marital
#-----------------

mea.Married    <- mean(Married)  ; mea.Married
mea.DivorWid   <- mean(DivorWid) ; mea.DivorWid
mea.Single     <- mean(Single)   ; mea.Single

........
........
........
........



# A new data frame for model-predicted (adjusted) prevalence

#    Subgroup: Females aged 50 years who have an average pattern of
#    all other factors in the model

new <- data.frame(Age      = 50,
                  Female   = 1,
                  East     = mea.East,
                  North    = mea.North,
                  DivorWid = mea.DivorWid,
                  Single   = mea.Single,
                  College  = mea.College,
                  Vocation = mea.Vocation,
                  Basic    = mea.Basic,
                  Office   = mea.Office,
                  Agricul  = mea.Agricul,
                  Pension  = mea.Pension,
                  Unempl   = mea.Unempl,
                  Other    = mea.Other,
                  WModer   = mea.WModer,
                  WHeavy   = mea.WHeavy,
                  PA.Moder = mea.PA.Moder,
                  PA.Inact = mea.PA.Inact,
                  BMIover  = mea.BMIover,
                  BMIobese = mea.BMIobese,
                  BMIveryo = mea.BMIveryo,
                  SmoEx    = mea.SmoEx,
                  SmoDai   = mea.SmoDai,
                  aModer   = mea.AModer,
                  aHeavy   = mea.AHeavy,
                  CVD      = mea.CVD,
                  RES      = mea.RES)

# Model-predicted (adjusted) prevalence

pr_     <- predict(m, type="response", new, se=TRUE)
pr      <- round( 100*pr_$fit, 2)
pr.lcl  <- round( 100*(pr_$fit - 1.96*pr_$se.fit),2)
pr.ucl  <- round( 100*(pr_$fit + 1.96*pr_$se.fit),2)
tab     <- cbind( pr, pr.lcl, pr.ucl)
Adj.Women.50  <- tab
Adj.Women.50


# A new data frame for model-predicted prevalence by age

#    Subgroup: Males aged 25 to 74 years who work in industry, have
#    a cardiovascular and lung disease and average pattern of all other
#    factors in the model


new <- data.frame(Age      = seq(25.5, 74.5, 1),
                  Female   = 0,
                  East     = mea.East,
                  North    = mea.North,
                  DivorWid = mea.DivorWid,
```

```
                  Single   = mea.Single,
                  College  = mea.College,
                  Vocation = mea.Vocation,
                  Basic    = mea.Basic,
                  Office   = 0,
                  Agricul  = 0,
                  Pension  = 0,
                  Unempl   = 0,
                  Other    = 0,
                  wModer   = mea.wModer,
                  wHeavy   = mea.wHeavy,
                  PA.Moder = mea.PA.Moder,
                  PA.Inact = mea.PA.Inact,
                  BMIover  = mea.BMIover,
                  BMIobese = mea.BMIobese,
                  BMIveryo = mea.BMIveryo,
                  SmoEx    = mea.SmoEx,
                  SmoDai   = mea.SmoDai,
                  aModer   = mea.aModer,
                  aHeavy   = mea.aHeavy,
                  CVD      = 1,
                  RES      = 1)

# Model-predicted (adjusted) prevalence

pr_     <- predict(m, type="response", new, se=TRUE)
pr      <- round( 100*pr_$fit, 2)
pr.lcl  <- round( 100*(pr_$fit - 1.96*pr_$se.fit),2)
pr.ucl  <- round( 100*(pr_$fit + 1.96*pr_$se.fit),2)
tab     <- cbind( pr, pr.lcl, pr.ucl)
CVD.RES.yes.Industry.M   <- tab
CVD.RES.yes.Industry.M



# Plot of model-predicted prevalence by age, professional field and diseases

#    Subgroups: Males aged 25 to 74 years in professional groups, with and
#    without cardiovascular & lung disease


par(mar=c(2, 5, 1, 1))
plot(25.5:74.5, CVD.RES.yes.M[,1],type="n", xlab="",ylab="",adj=0.5, ylim=range(0, 73), axes=F)

# Horizontal axis (Age)
axis(1, at=seq(25,75,1), labels=F, tcl=0)
axis(1, at=seq(25,75,5), labels=F, tcl=-0.2)
axis(1, at=seq(30,70,10),labels=c("30","40","50","60","70"), tcl= -0.4, padj= -0.5)

# Vertical axis (prevalence of symptoms)
axis(2, at=seq(0,60,1),  labels=F, tcl=0)
axis(2, at=seq(0,70,5),  labels=F, tcl=-0.2)
axis(2, at=seq(0,70,10), labels=c(" 0","10","20","30","40","50","60","70"), tcl= -0.4, las=2,
hadj= 0.8)

grid(lty=3, lwd=1)
box()

text(29,70, "CVD & LD ", cex=1.1, adj=0)
text(41,13, "NoCVD, NoLD ", cex=1.1, adj=0)
mtext( "Age(yr)", side=1, cex=0.8, line=2.5)
mtext( "%",       side=2, cex=0.8, line=3, las=2)

# Males with CVD and RES
lines(25.5:74.5, CVD.RES.yes.Pension.M[,1],  lty=4, lwd=1 )
lines(25.5:74.5, CVD.RES.yes.Agricul.M[,1],  lty=3, lwd=1 )
lines(25.5:74.5, CVD.RES.yes.Office.M[,1],   lty=2, lwd=1 )
lines(25.5:74.5, CVD.RES.yes.Industry.M[,1], lty=1, lwd=1 )
lines(25.5:74.5, CVD.RES.yes.M[,1],          lty=1, lwd=3, col="Gray65" )
```

```
# Males without CVD and RES
lines(25.5:74.5, CVD.RES.no.Pension.M[,1],  lty=4, lwd=1 )
lines(25.5:74.5, CVD.RES.no.Agricul.M[,1],  lty=3, lwd=1 )
lines(25.5:74.5, CVD.RES.no.Office.M[,1],   lty=2, lwd=1 )
lines(25.5:74.5, CVD.RES.no.Industry.M[,1], lty=1, lwd=1 )
lines(25.5:74.5, CVD.RES.no.M[,1],          lty=1, lwd=3, col="Gray65" )
```