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Association of self-reported different aspects of workplace environment and general well-being with maximum workload – A cross-sectional study

Word count: 11,029 words

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Master Degree Project in International Heath, 30 credits. Spring 2018
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Abstract

Introduction

Cardiovascular disease (CVD) is the leading cause of death globally and similarly in United Kingdom (UK), accounting for 31% and 45% annual deaths respectively. Workplace environment consists of different elements (e.g.- physical and psychosocial environment, intra and extra organizational settings) and interrelationship of employer and employee, playing an important role on workers' health. Current study aims to identify the association of different aspects of workplace environment and general well-being with maximum workload (MW) in a working population in UK.

Method

A cross-sectional study has been done including a total of 77,781 working people aged 39 to 72 years old who participated voluntarily in the UK Biobank baseline assessment cohort study. Exposures were self-reported that included information about both physical and psychosocial aspects of workplace environment and general well-being. The outcome variable was maximum workload calculated during electrocardiogram (ECG) stress test. Three different statistical models were tested through ordinal logistic regressions using the SPSS software.

Results

No/low health satisfaction was associated with reduction in maximum workload and this association was constant in all analytical model, both in crude (B -0.786, 95% CI -0.825, -0.748) and adjusted models (B -0.866, 95% CI -0.910, -0.823). Other variables regarding different aspects of workplace environment and well-being showed no statistically significant result on the adjusted models.

Conclusion

Health satisfaction may be considered as an important determinant of CVD among middle and old-aged working population. Future research required to establish the result and to formulate preventive measures in workplace for better health outcome of workers.

Used abbreviations

ANS – Autonomic nervous system

BMI – Body mass index

CASE – Cardiac Assessment System for Exercise Testing

CVD – cardiovascular diseases

ECG – Electrocardiogram

ERI model – Effort-reward imbalance model

MW – Maximum workload

NCD – Non-communicable diseases

PSF – Psychosocial factors

SD – Standard deviation

TDI – Townsend deprivation index

UK – United Kingdom

WHO – World Health Organization

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1 Introduction

1.1 Global context of cardiovascular diseases

Non-communicable diseases (NCDs) have been identified as 21st century's dominant and slow motioned emergency public health challenge. Cardiovascular disease (CVD) is a major contributor to the burden of non-communicable diseases (NCDs) (1). CVD is the leading cause of death globally, and thus responsible for the highest number annual deaths worldwide compared to any other causes. CVD is responsible for accounting one in every three deaths worldwide (2). According to WHO, in 2015, the number of deaths due to CVDs were around 17.7 million, representing the leading cause (31%) of deaths globally (3). It is assumed that 23.6 million people will die due to CVDs, mainly because of heart disease and stroke by the year of 2030 (4).

1.2 CVDs in Europe and in UK

The leading cause of death in Europe is CVD (5) and causes more than half of all deaths across the European Region. Moreover, among them 80% of premature heart disease and stroke is preventable (6). In Europe, over 85 million people were existing with CVD and the number of new cases are less than 11.3 million (7). CVD has been mentioned as the principle cause of death in UK and causing 245,000 deaths annually, accounting for premature deaths respectively 36% in men and 27% in women (8). More than a quarter of total number of all deaths and 15% of all DALYs lost in England and Wales occurred due to cardiovascular disease. (9) A self-reported study among employees in UK, around 80,000 people reported to have CVD that is either caused or became worse by the work (8).

1.3 Cardiovascular diseases

Disorders of heart and blood vessels that include cerebrovascular disease, coronary heart disease, rheumatic heart disease and other conditions (peripheral vascular disease, congenital heart disease and hypertension) of cardiovascular system are known as cardiovascular diseases (CVDs) (10). According to WHO, a group of disorders of blood vessels and heart consisting of different conditions are termed as cardiovascular disease (4). The exact causes of developing CVD is still not clear and a number of risk factors can increase the chance of developing CVD in an individual (11). Many risk factors are associated with development of cardiovascular disease and they can be divided in – modifiable risk factors and non-modifiable risk factors (12). High blood pressure, high serum-cholesterol level, diabetes mellitus, alcohol intake, smoking habit, unhealthy dietary habit, obesity and lack of physical activity have already been established as well-known risk factors for CVD (13).

1.4 Workplace environment

The environment, in which people work is simply known as workplace environment. But, in reality, it is a very wide category consisting of different elements. It includes not only the physical setting of a job place, but also encompasses various job characteristics, comprehensive organizational features and other aspects of setting that is extra organizational. All these different properties of the workplace environment can affect physical well-being or psychosocial well-being or both. On the other hand, it can also affect beneficially both health aspects in an individual - the physical aspect and psychosocial aspect (14). Workplace environment is the total sum of the interrelationship between the employers and workers and also the entire environment where people work, consisting of technical, organizational and human environment (15).

1.5 Workplace environment and CVD

There is an old relationship between work environment and increased risk of cardiovascular diseases (16). The possible mechanism behind the association between the work environment and the risk of developing CVD is still not clear. Directly activated neuroendocrine system by the work stressors could be the underlying mechanism behind CVD. On the other hand, unhealthy lifestyle behaviors like – unhealthy dietary habits, sedentary lifestyle, excessive consumption of alcohol or smoking can also be responsible for such a relation. (17). In cross-sectional studies among men, reduced variability of heart rate has been found to be associated with work stress due to repeated activation of the ANS, one of the main axis of neuroendocrine stress responses. (18,19). Moreover, hypothalamic–pituitary–adrenal axis may be dysregulated by the work condition and that is also related to the disturbance of the circadian rhythm of cortisol and the development of the metabolic syndrome (20–22). Most research have been conducted on finding relationship between work environment and cancer, reproductive issues and diseases of musculoskeletal system. So far, less attention has been paid to the research in finding association between different aspects of the work environment and diseases of cardiovascular system (23).

1.5.1 Psychosocial aspects of workplace environment and CVD

The possible mechanism behind this relation could be of two types such as – direct mechanism (through physiological variable) and indirect mechanisms (through behavioral risk factors). Changes in physiological variable may include rise in blood pressure and serum cholesterol level, increase in left

ventricular mass, higher concentrations of different hormones (e.g. - catecholamines), plasma fibrinogen and glycated hemoglobin. Different behavioral risk factors like smoking and drinking habit may also influence the relation indirectly. But, social support may help to reduce the job strain effect on the above mentioned effects (24). Two models are commonly used to assess the work condition and they are - the 'job effort-reward imbalance model'(ERI) and the 'job demand-control model' (25,26).. In a prospective study among blue collar male workers, association between low reward or low status control and high extrinsic (e.g. – work pressure) or intrinsic (e.g. – high need for control) efforts has been established that can predict newly developed cardiovascular events independently (27). Another two independent studies described the role of these variables in explaining cardiovascular risk factor prevalence (25). An average of 50% more risk for CVD has been observed related to work stress among the employees (28). Another study have also been conducted to explore the association between work stressors and CVD which experienced the more risk for CVD (29). Few studies have demonstrated that psychological pressure and CVD incidence can be affected by high levels of job strain (30–34).

In the 'INTERHEART' study involving 52 countries, 32.5% population attributable risk has been found for myocardial infarction that derived from modifiable psychological factors (stress at home, stress at work, stress due to financial condition, life events) and placed PSF in third position as a risk factor for myocardial infarction (35). Also, consistent results have been found about the relationship between job strain and higher risk for cardiovascular disease on the exposed people (24). Another study found strong association between decreased job satisfaction with low or moderate level of perceived stress, but the association was different for men and women. Still, there is a research gap between job satisfaction and CVD risk factors (e.g. – Blood pressure, BMI, level of blood cholesterol, smoking and alcohol habit) adjusted to age (36).

1.5.2 Physical aspects of workplace environment and CVD

Employees spend about 8 to 12 hours in their workplace, surrounded by different physical environments (e.g. – temperature, quality of air, noise and lighting conditions) that can affect well-being, work performance and productivity of the employee (37). A strong and positive association between exposure to tobacco smoke from other people smoking and higher risk of CVD morbidity and mortality has been detected. Also, different chemical exposures found responsible for elevating the CVD risk (38). Noise is an unpleasant sound which commonly causes hearing loss that is the most common among occupational diseases and also responsible for creating stress among employees. Excessive noise elevates the level of plasma hormones such as – cortisol and adrenaline and increase the heart rate that may trigger the CVD risk factors (39–41). A cohort study among male workers suggested that chronic exposure to noise in

workplace can independently rises systolic blood pressure (42). Hazardous chemical exposure was also reported to increase the physiological levels of brain-derived neurotrophic factor (BDNF), leptin and other neurotransmitters (e.g. – serotonin, catecholamines and dopamine), which all together increase the desire of food intake and as a result increase the CVD occurrence among the workers (43–45). Previous studies have shown that occupational exposure to high level of hazardous chemicals among workers of a petrochemical factory result in high prevalence of hypertension (46) and that high level styrene exposure increased the prevalence of CVD in exposed workers, compared to those with a low level of styrene exposure (45,47). Different occupations like – agricultural workers, construction workers, miners, armed forces personals, fire fighters, manufacturing workers etc. are exposed to different levels of heat exposure in their workplaces. Combination of external heat (from environment) and internal body heat (from metabolism) causes total heat gain. In the workplace, there are two types of sources for external heat exposure such as – weather related heat exposure and man-made heat exposure (48). Chronic exposure for heat in the workplace has been reported to have adverse and long-term effects on health (e.g. – cardiovascular diseases) (49). Another study, both noise and heat exposure in the workplace found to be associated with cardiovascular problems (50). Both heat and cold exposure in the workplace are linked to higher risk of acute onset cardiovascular events and significant rise in silent ST depression reported to have correlation with cold exposure (less than 20^0) among women workers (8). Slightly increased CVD mortality risk has been detected due to occupational exposure of fiber dusts among women textile workers of China (51).

1.5.3 General well-being and CVD

Well-being is a wider concept that consists of a range of theoretical approaches such as – eudaimonic well-being, social well-being and hedonic well-being. Positive components of psychological health can be reflected by positive psychological well-being and characterize individuals who feel good about their life as well as they can function well (52). There is enough evidence for an established association between positive psychosocial well-being and cardiovascular health. Decreased risk of CHD incidents and mortality has been found to be associated with optimism in few studies (53,54). A study among middle aged cohort investigated the association of emotional vitality and optimism with CHD incident, reporting a consistent association between higher levels of well-being and lower risk of CHD (52). Moreover, associations of Coronary heart disease with three specific stress-related negative emotions namely anger, depression and anxiety - were established by another study (55). Individuals with high level of psychological stress are at higher risk of incident CVD compared to less stressed individual (54). The exact mechanism behind this association is still obscure. However, a possible mechanism could be an excessive hypothalamic–pituitary–adrenal (HPA) axis and sympathetic-adrenomedullary system activation. Simultaneously, alteration of autonomic cardiac control, acceleration of atherosclerosis and health-related behaviors are also involved. Proposed potential mediators for psychological stress and

CVD relationship are multiple stress-related hormones such as – catecholamines and cortisol (54). In elderly people, cardiovascular disease is a psychosomatic disease. Nonetheless, most previous researches investigated different health status changes that caused as a result of negative emotion and only few researches that focused on relationship between positive emotion and CVD. Positive emotion is considered as one of the protective factor in elderly people against health problems and somehow remain ignored by the researchers. Also, a significant relationship of blood pressure with positive emotion has been found in elderly people (56). Moreover, life satisfaction has been counted as a predictor of morbidity and mortality, independent of objective measures of health status. A strong linear relationship has been observed between low satisfaction of life with risk of CVD while assessed by using Framingham Risk Score (FRS) among the Polish adults (57).

1.6 Further cardiovascular research opportunities from large sample

Different modifiable and non-modifiable risk factors, cause and consequences of CVD have been stated by many researchers in different epidemiological studies at different time point conducted either within individual countries or globally (58). Studies have also established how the traditional and novel risk factors of CVD can play a vital role in development of the disease. The measures to predict the subclinical condition of CVD or related to CVD as well as assessment of short or long-term risk of CVD are also available. Such measures can help identifying individuals who would get maximum benefit from risk-factor interventions, and helped developing and implementing multiple intervention strategies (59). For instance, the INTERHEART study, a case-control study conducted to detect the association between myocardial infarction and effect of modifiable risk factors in 52 countries (60). Same study was used successfully as an evidence-based study for implementing feasible and low-cost strategies for prevention of chronic diseases in India (61). The study also highlighted how the potential and modifiable risk factors playing their role in the causation path of acute myocardial infarction. Similarly, another project conducted by the WHO, called the MONICA (Multinational monitoring of trends and determinants in cardiovascular disease) project, played a significant role in giving training to the cardiovascular epidemiologist and also by creating standards for measurement which can be applied internationally (62). The Framingham Heart study was successful to detect a range of risk factors that were important and associated with cardiovascular disease (63). Moreover, the Seven Countries Study influenced the treatment for the primary and secondary prevention of different events of cardiovascular health (58). Similarly, the UK Biobank is a very large and population-based prospective cohort study and was established for detailed investigations of disease determinants (both genetic and non-genetic) among middle and old aged population (64). This study recruited 500,000 participants in their baseline assessment study to collect health and health related information and includes ongoing comprehensive

follow-up studies to characterize many different health-related outcomes. Overall, the UK Biobank study aimed to combine wide-ranging and more precise assessment of different exposures and maximize the access to available resources for promotion of innovative science. Such a large and prospective cohort can be used to study recognized and novel risk factors of several diseases in a much wider range, as well as to assess exposures before the onset of the disease (64). Many cohort studies, however, consist of collection of less comprehensive data in spite of having large sample sizes and biological samples, resulting in production of few outcomes. To address all these issues, UK Biobank was created combining a large sample size and a broad range of data regarding exposures and outcomes that could be useful in diagnosis, treatment and prevention of diseases among middle and old age people. This is a well-designed and reliable cohort for detecting and generalizing associations between health outcomes and most characteristics of the baseline study. Three-fold increased interest for UK Biobank data has been found in last 4 years, more notably from international researchers and predominantly from researchers of United states and mainland Europe (58). For example, more recently a study using UK Biobank data established an association between higher likelihood of adiposity and a subset of favorable adiposity alleles which in turn associated with decreased risk of hypertension and heart disease (65). Another genome-wide analysis study identified the link between novel genetic variants and phenotypes of blood pressure (66). Exploration of strong association between exposure and outcome along with development of risk prediction model is possible from such a dataset with or without validation (67). Tremendous opportunities for different researches are present within the UK Biobank data which can be used in numerous ways by the researchers to diagnose, treat or prevent cardiovascular diseases.

On the other hand, studies with small sample size can be concluded with statistically less powerful results which could hide the real effect or other associated minor effects and may cause difficulty in generalizing the result.

1.7 Maximum workload as a predictor of CVD

Maximum workload (MW) or maximum exercise capacity has been defined as the maximum amount of physical exertion that can be sustained by a person. Adequate testing of several body systems functions, particularly the functions of circulatory system and respiratory system, can be assessed during exercise (68). Exercise workload is an important prognostic variable that can be derived from exercise stress test. Exercise test is a non-invasive and relatively inexpensive clinical tool and exercise capacity is a strong and independent outcome predictor (69). A very strong and independent predictor of premature mortality is maximal exercise capacity and the achieved maximal workload can be measured in Watts or MET (metabolic equivalent or O_2 consumption at rest) (70,71). An association has been found between good exercise capacity and reduced number of myocardial infarction, ischemia with ST-segment depression, revascularization and mortality (72). For all-cause mortality, exercise capacity was found as better

predictor compared to maximum heart rate achieved during exercise test and the angiographic severity of coronary artery diseases (72). In another study, a correlation was found among right ventricular systolic function indices with maximum exercise capacity in healthy individuals (73). In men with or without existing cardiovascular disease, weak exercise capacity has been proven as an important and strong marker of having increased risk of CVD (69).

On the other hand, systolic blood pressure and age-predicted maximal heart rate achieved during the exercise stress test seem to be less effective in measuring the exertion level of a patient with myocardial ischemia (74). Also, 85% maximal predicted heart rate achievement significantly misjudged the capacity of exercise and inducible ischemia and thus cannot be counted as a valid diagnostic or functional endpoint of exercise (75). Irrespective of age and gender, higher workload that is achieved during exercise stress test eligible for prediction of improved survival rates (69,76,77).

1.8 Aim

This thesis aims to identify the association of different working environment related factors and general well-being with maximum workload in a working population in the United Kingdom. Maximum workload was measured by a screening method (ECG stress test) in Watts (W). If a positive association is found, better working environment can be created or maintained and better policies can be structured or implemented in the workplace to prevent cardiovascular diseases among working people's and thereby the rate of non-communicable disease related morbidity and mortality can be reduced.

1.9 Research question

Are different aspects of workplace environment and general well-being associated with maximum workload recorded during ECG stress test among current or previous working population?

This study hypothesized that exposure to different aspects of workplace environment and general well-being could be associated to the risk of cardiovascular disease when measured by the stress test derived maximum workload.

Null hypothesis (Ho): There is no association of different aspects of workplace environment and general well-being with the risk of cardiovascular disease among current or previous exposed workers compared to non-exposed population.

Alternative hypothesis (H_1): There is an association of different aspects of workplace environment and general well-being with the risk of cardiovascular disease among current or previous exposed workers compared to non-exposed population.

2 Methods

2.1 Study design and setting

A cross-sectional study was done to examine the association between working environment and maximum workload which was measured by values recorded during the electrocardiogram test (ECG). This study uses data from the UK biobank which is a large, population-based and comprehensive prospective cohort study (64), and was first conducted among 500,000 voluntary participants having different socio-economic and ethnic backgrounds and the large cohort size was chosen based on the statistical power calculations. The baseline data were collected between the year of 2006 to 2010 in 22 assessment centers situated in different locations of United Kingdom (UK) and in both urban and rural settings. At baseline, the aim was to assess different exposures and familiar risk-factors of diseases. Longitudinal follow-up is ongoing for characterizing different and large number of health-related outcomes.

Figure 2: Different study locations in UK

2.2 Study population and sampling

In this study, analysis was restricted to factors related to working environment and general well-being and only included those who participated in the stress ECG recording test (n = 77,960) at the baseline assessment study. Participants with congenital heart problems (n = 103) or with chronic rheumatic heart

diseases (n = 76) at the baseline assessment were excluded from the current study. This study finally included 77,781 participants of both sexes (male & female) from the UK Biobank cohort study within an age range of 39 to 72 years.

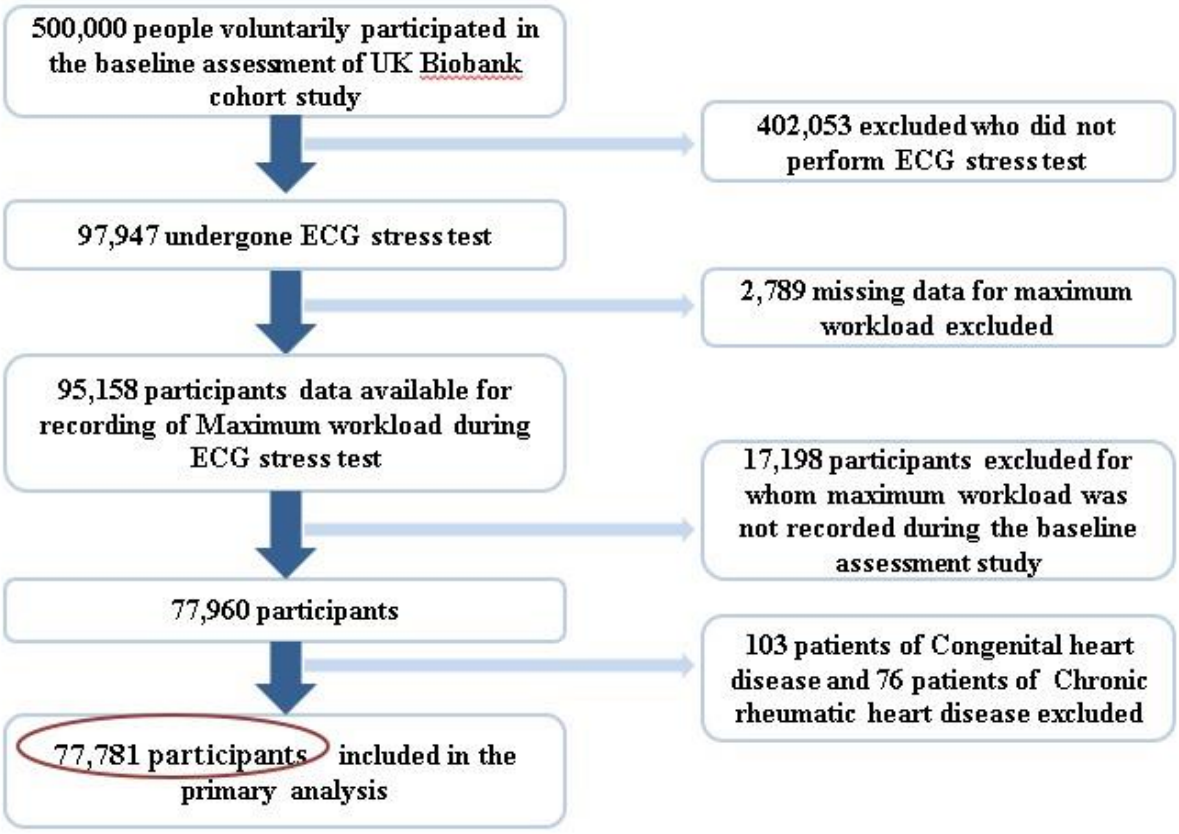

Figure 3: Inclusion and exclusion criteria

2.3 Data collection and procedure

For the collection of data participants were invited by mail and only voluntary participants joined the UK Biobank baseline assessment study. Selected participants from the baseline study reported about different medical and health conditions, socio-demographic and lifestyle information, employment and working environment conditions, family and medical history and about intake of medication during baseline assessment and assistance of trained health professionals were used when required. Data was collected by using different measures – self-completed touch-screen questionnaire, computer assisted brief interview (CAI), different physical and functional measurements and biological sample collections (blood and urine) (64). All these processes take only few minutes to complete and most of them were automatically stored to the central system. Some processes require a single trained staff either to monitor or assist the procedure. Short descriptions of all processes are given below (78) –

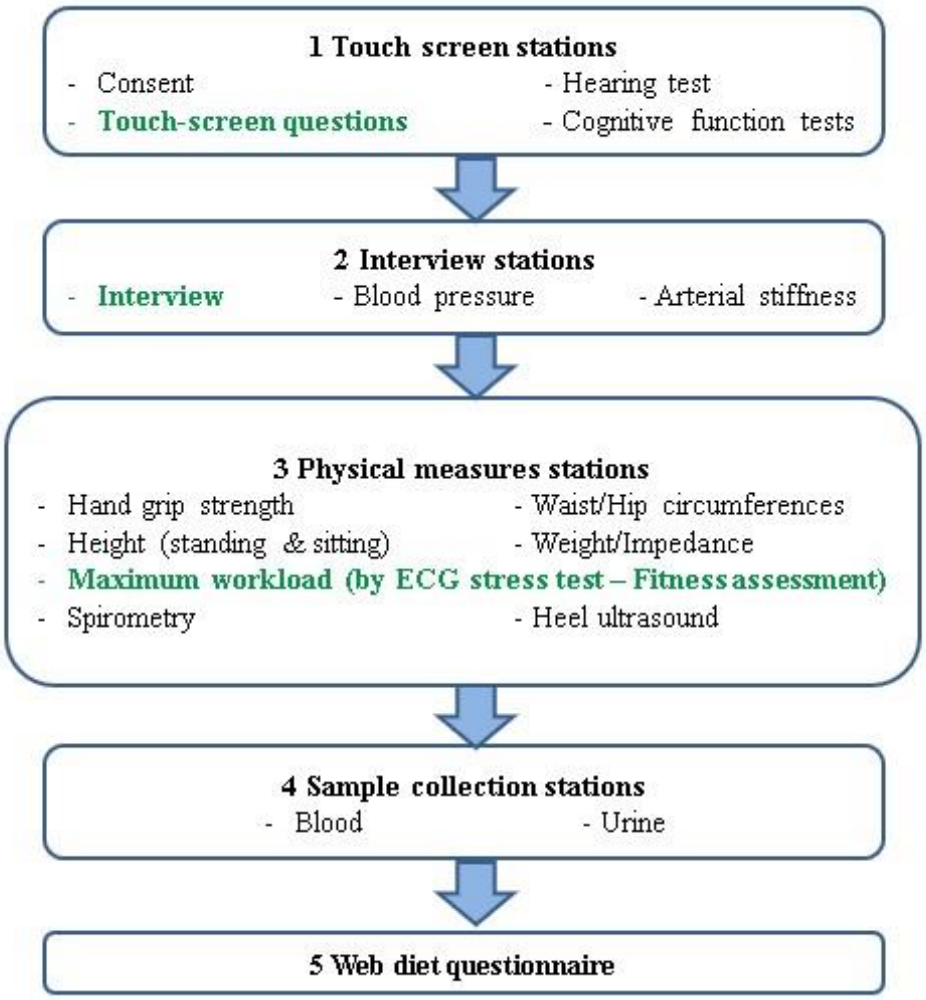

Figure 4: Different steps of assessments

2.3.1 The UK Biobank Questionnaire –

2.3.1.1 Self-completed touch-screen questionnaire:

Questions were prioritized depending on some standard criteria and in relation to potential exposures and confounders. It was a touch-screen questionnaire which was easy to fill, allowed more privacy for the participants and was automatically stored safely. Cognitive function test was done as a part of this assessment. Questionnaire was formulated based on previously used platforms by other large-scale studies and was built specifically for the UK Biobank study. This section was used to collect majority of the information.

2.3.1.2 Computer assisted personal interview (CAPI):

Information provided during the touch-screen procedure that required more detail or in-depth questioning, was collected by using this procedure. This consisted in a 5 to 10 minutes personal interview and was controlled by trained staff. Participants completed a 'pre-visit aide memoire' to provide difficult to recall or time-consuming information.

2.3.2 Physical and functional measurement -

Baseline measurements were selected from a piloted study that was conducted before the baseline assessment study. Only selected measurements from the pilot study were included in the baseline study and several physical and functional measurements were taken from all participants. Blood pressure and pulse rate, weight, height, waist and hip circumference, bio-impedance, handgrip strength, spirometry, bone densitometry were measured by trained health staff and 4-lead electrocardiogram (ECG) were conducted at this stage. Maximum workload was calculated during the ECG stress test for each individual.

2.3.3 Biological sample collection -

Blood and urine samples were collected as a part of baseline assessment study.

2.4 Variables

Multiple variables were investigated to address the main purpose of this study. Detailed explanation of the main variables with collecting procedure are given as below -

2.4.1 Independent variables

Different aspects of workplace environment (physical aspects and psychosocial aspects) and general well-being

Employment status and job -related details were taken from the participants using both processes and all information given by the participants were self-reported. Firstly, participants information were gathered with respect to their current and/ or previous occupation which later used to classify them in different job groups following 'Standard Occupational Classification 2000' (79). Considered physical aspects of workplace environment are – exposure to noise, heat, cold, dust, chemicals or fume, passive smoking in the workplace. As psychosocial aspects of workplace environment one variable was considered such as – work or job satisfaction. For both physical and psychosocial working environment same patterned questions were asked to all participants (Table 1) and these questions were formulated for the UK Biobank Study. Four responses were used for each variable related to physical aspect of workplace environment depending on the answers of the participants. Nine different type of responses were used for psychosocial aspects related to workplace environment that was also based on participants answers. Four different types of answer options that were used for each variable related to physical aspect of workplace environment were recoded as two responses, where 1 stands for Yes and 0 stands for No (Table 1). The answers that is chosen by the participants as 'do not know' were recoded as missing data (999). General well-being factors included happiness, family relationship and health satisfaction. Different type of responses (Eight responses for each of the three well-being variables) were used for general well-being factors that was also based on participants answers. All variables were recoded similarly as the physical aspect and all recoded with binary scales where 1 represented as Yes and 0 represented as No. Similarly,

who preferred not to answer and who chose do not know answer were recoded as missing data. Only the variable 'Work/job satisfaction' had one extra response option than well-being factor responses named – I am not employed, was also recoded as missing data = 999.

Table 1: Questions used to know about different exposures of workplace environment and general well-being

Different aspects of workplace environment	Used questions	Used scales	
		Original options	Recoded options
A. Physical aspects of workplace environment			
		4 options	2 options
1)Workplace very noisy	"Thinking about the place where you worked: Was it very noisy?"	a. Often b. Sometimes	Yes (1)
		c. Rarely or never	No (0)
		d. Do not know	Missing data (999)
2) Workplace very hot	"Thinking about the place where you worked: Was it very hot?"	Same as above	Same as above
3) Workplace very cold	"Thinking about the place where you worked: Was it very cold?"	Same as above	Same as above
4) Workplace very dusty	"Thinking about the place where you worked: Was it very dusty?"	Same as above	Same as above
5) Workplace full of chemical or other fumes	"Thinking about the place where you worked: Was it full of chemical or other fumes?"	Same as above	Same as above
6) Workplace had a lot of cigarette smoke from other people smoking	"Thinking about the place where you worked: Was there a lot of cigarette smoke from other people smoking?"	Same as above	Same as above
B. Psychosocial aspects of workplace environment			
		8 options	2 options
Happiness	In general, how happy are you?	a. Extremely happy b. Very happy c. Moderately happy	Yes (1)
		d. Moderately unhappy e. Very unhappy f. Extremely unhappy	No (0)
		g. Do not know	Missing data (999)

		h. Prefer not to answer	
Health satisfaction	In general, how satisfied are you with your health?	Same as above	Same as above
Family relationship satisfaction	In general, how satisfied are you with your family relationships?	Same as above	Same as above
Work/job satisfaction	In general, how satisfied are you with the work that you do?	9 options	2 options
		a. Extremely happy b. Very happy c. Moderately happy	Yes (1)
		d. Moderately unhappy e. Very unhappy f. Extremely unhappy	No (0)
		g. I am not employed h. Do not know i. Prefer not to answer	Missing data (999)

2.4.2 Dependent variable

Maximum workload during fitness test

ECG bike test was conducted to calculate the maximum workload of an individual by attaining maximum workload during the test. The used ECG device is a CAM-USB 6.5 that had been operated by using the Cardiosoft v6.51 software and the used stationary bike was an eBike that was operated by using the Firmware v1.7 software. This test consisted of three phases – Pre-test phase (resting ECG for 15 seconds), Activity phase (bike pedaling for 6 minutes) and Recovery phase (rest on bike for 1 minute) and was tested by using a stationary e-bike in conjunction with a 4-lead electrocardiograph (ECG) device. Few screening questions were asked by the operator following a questionnaire about existing medical problems declared by doctor, and also about chest pain and physical activities to the participants. Cycling level and rate was determined by considering different risk categories and an absolute maximum workload was assumed for each participant prior to the actual test using the following formula: (80–82):

Absolute maximum workload = 105.2749 + (-0.0935 x AGE) + (-0.0280973 x AGE x AGE) + (2.809493 x SEX) + (119.0087 x HEIGHT) + (0.309456 x WEIGHT) + (-2.698067 x RHR) + (0.0090985 x RHR x RHR) + (-0.3783405 x AGE x SEX) + (60.72548 x HEIGHT x SEX) + (-0.15016 x WEIGHT x SEX) + (-0.3730664 x RHR x SEX) + (0.0180811 x RHR x AGE)

Here, AGE was counted from date of birth in years, HEIGHT was measured in meters in the biometric stage of the assessment, WEIGHT was also taken in the biometric stage which was measured in Kilogram (Kg) and RHR = Resting heart rate that was counted as beats per minute (bpm). Finally, maximum workload was calculated in Watts which was actually attained by each participant during the ECG stress test and automatically measured by the operating software called Cardiac Assessment System for Exercise Testing (CASE), Cardiosoft v6 (6.51). Cardiac Assessment System for Exercise Testing (CASE) software system is an innovative algorithm that help to assess cardiac function more conveniently during exercise and has a greater diagnostic confidence with proven clinical excellence (80). Moreover, the final recorded value of maximum workload was not calculated using any formula or algorithm and did not include participants age or sex anywhere in the value recording process.

2.4.3 Covariates

Age:

Age was calculated in years at the day of visiting assessment center during the baseline assessment study and was counted from self-reported individual's date of birth in years.

Sex:

Participants of both sexes - male and female were included in the baseline study. Participants sex were acquired from the central registry which was updated by the participants.

Minor ethnic group:

Participants did self-reporting about their ethnicity in the touch-screen questionnaire procedure**.** Ethnicity was then recoded as dividing them into major and minor ethnic groups depending on their total percentages. Major ethnic group only includes White, while minor ethnic groups consisted of other ethnic backgrounds – Black, Asian, Mixed and Others (Table 2).

Socio-economic status:

Socio-economic condition was detected by the 'Townsend deprivation index score' which is a census-based index and calculated by four census-based variables which are – households without a car, households not owner occupied, overcrowded households and persons unemployed. Each variable divided by the appropriate count of households or persons to get a percentage score and then standardized using a Z-score. The single value obtained from the sum of the standardized scores are known as Townsend deprivation index (83). High material deprivation indicated by a positive value and negative value indicates affluence. In the baseline study, TIA was calculated immediately prior to joining of the participants and that was based on preceding national census output areas. A score corresponding to the output area in which their postcode is located were assigned to each participant.

Educational qualification:

Participants were divided into two main categories based on their college or university level degrees. One group had qualification equal to or more than college level degrees (college/university degree) and also included people having different professional degrees. The other group of people has education below college level to not educated at all (Table 2).

BMI

Body mass index is a continuous variable that was constructed by calculating from the measured individual's height and weight during the baseline assessment. Measurements of the height and weight were done by the trained staffs.

Moderate physical activities

Number of days of physical activities per week that was done by each participant was self-reported by the participants during the stage of touch-screen questionnaire. Participant who did physical activities at least more than or equal to ten minutes (except walking) in one day were counted as moderate physical activity done per day and were recorded with the number of days of moderate physical activity in a week with eight responses ranging from zero to seven days (Table 2).

Alcohol intake frequency

Frequency were recorded depended on consumption of alcohol by an individual participant in general that was asked by a simple question and were reported by the participants. Responses were six in numbers such as – never, special occasions only, 1-3 times per month, once or twice a week, 3-4 times a week and daily or almost daily. These responses were used similarly in the analysis as the meaning of different responses vary from each other (Table 2).

Smoking status

Participants completed questionnaires about their smoking status whether they smoke currently or previously was a smoker. The state of never smoking was also present in the responses and were chosen by those participants who never smoked at all (Table 2).

Occupation (Job code):

Professions of the participants expressed as 'job code' that were classified into nine major occupational groups following 'Standard Occupational Classification 2000' (79) and participants were allotted to a specific occupational group according to their current or previous profession.

Job involves shift work and Job involved shift work

These are two different co-variates and both conditions that job recently involve shift work or not and also previously involved shift work or not were mentioned by the participant. 'Jobs involved shift work' was expressed with binary response of either yes or no. The other variable 'Job involves shift work' was recoded with three responses – never, sometimes and usually or always. Shift work means day shift work or night shift work or both (Table 2).

Working hours

Working duration of the participants were self-reported and were recorded in hours for one week (Table 2).

Table 2: Questions used to know about different co-variates

Co-variates	Used questions	Used scales	
		Original options	**Recoded options**
Demographics			
		8 Options	2 options
1. Ethnic group	An amalgam of sequential branching questions asked as part of the touchscreen questionnaire.	a. White	Major ethnic group (1)
		b. Mixed c. Asian or Asian British d. Black or Black British e. Chinese f. Other Ethnic group	Minor ethnic group (0)
		g. Do not know h. Prefer not to answer	Missing data (999)
2. Educational Qualifications	"Which of the following qualifications do you have? (You can select more than one)"	a. College or University degree b. Other professional qualifications e.g.: nursing, teaching	≥ College or university level degrees (1)
		c. A levels/AS levels or equivalent d. O levels/GCSEs or equivalent e. CSEs or equivalent f. NVQ/HND/HNC or equivalent	≤ College or university level degrees (0)
		g. None of the above h. Prefer not to answer	Missing data (999)
Health and lifestyle			
1.Smoking status	This field summarises the current/past smoking status of the participant.	4 options	2 options
		a. Previous b. Current	Yes (1)
		c. Never	No (0)
		d. Prefer not to answer	Missing data (999)
2.Alcohol intake frequency	"About how often do you drink alcohol?"	7 options	6 options
		a. Daily or almost daily b. Three or four times a week c. Once or twice a week d. One to three times a month e. Special occasions only f. Never	a. Daily or almost daily (1) b. Three or four times a week (2) c. Once or twice a week (3) d. One to three times a month (4) e. Special occasions only (5) f. Never (0)

		g. Prefer not to answer	Missing data (999)
3. Number of days per week of moderate physical activity	"In a typical WEEK, on how many days did you do 10 minutes or more of moderate physical activities like carrying light loads, cycling at normal pace? (Do not include walking)"	Options include – a. 0 to 7 days	0 day to 7days
		b. Do not know c. Prefer not to answer	Missing data (999)
Occupational characteristics			
Job involves shift work	"Does your work involve shift work?"	6 options	2 options
		a. Sometimes b. Usually c. Always	Yes (1)
		d. Never/Rarely	No (0)
		e. Do not know f. Prefer not to answer	Missing data (999)
Job involved shift work	"Did you ever work shifts (day and/or night shifts**) for this job?"	2 options	2 options
		a. Yes	Yes (1)
		b. No	No (0)
Work hours (per week)	"On average, how many hours a week did you work?"	Entered a precise number of hours	Same as original

**Day-shifts were defined as work in normal daytime hours or morning, afternoon or evening work. Night-shifts were defined as work for at least 3 hours between midnight and 5am.

2.5 Statistical analysis

SPSS software was chosen to perform all statistical analysis. IBM SPSS Statistics 22 version has been used for the purpose of recoding and analysis of the data. At first, all required variables were placed to create the dataset in a sav format file and then was imported to the SPSS software. Then, desired variables were recoded and reordered according to the need of the analysis. All the independent variables used in this study were recoded as binomial outcome (Yes = 1 and No = 0) and the outcome variable used was ordered to set as 10^{th} percentile groups. The outcome variable was recorded during the ECG stress test as a continuous variable for which the measurement unit was Watts (W). But, this variable failed to meet the assumption of normality when tested. So, logit conversion was applied which also did not meet the normality assumption. Finally, the outcome variable was converted to a categorical variable (ordinal) of 10^{th} percentile (10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th}, 70^{th}, 80^{th}, 90^{th} and 100^{th}). SPSS software was also used for getting frequency distributions and numerical summaries of the used variables.

Chosen variables and data overview were summarized initially and Ordinal logistic regression models were performed for the analysis of data. The values for significant result in all analysis were set as < 0.005 for the p-value (p = < 0.005) and 95% for the confidence interval (95% CI), adjusted for multiple comparisons according to Bonferroni's approach. In total, three models were tested to assess the crude and adjusted association between predictor variables, dependent variable and covariates and ordinal logistic regression models were tested as the dependent variable was converted to an ordinal variable. (Table 3) In model I, crude analysis was done for each predictor variable and each co-variate where the outcome variable was maximum workload. In every model, the outcome variable was fixed to maximum workload. Another two models (model II and III) were done as adjusted analysis to compare with the crude results. Each predictor variable was adjusted for all co-variates in model II and all predictor variables adjusted for all co-variates together in model III. The used models are described in detail on a table below (Table 3).

Table 3: Models used for the analysis

Model no.	Types of used model	Variable(s)	Outcome variable	Adjusted variable
I	Generalized Linear Model (Ordinal Logistic Regression) (Table 7)	Workplace very noisy, Workplace very hot, Workplace very cold, Workplace very dusty, Workplace full of chemicals or other fumes, Workplace had a lot of cigarette smoking from people smoking, Work/Job satisfaction, Happiness, Family relationship satisfaction, Health satisfaction, Age, Sex, Qualification, Ethnic group, Socio-economic status, Alcohol intake frequency, Smoking status, BMI, Number of days per week of moderate physical activity, Occupation, Job involves shift work, Job involved shift work	Maximum workload	N/A
II	Generalized Linear Model (Ordinal Logistic Regression) (Table 8)	Workplace very noisy,	MW	Age, Sex, Educational qualification, Ethnic group, Socio-economic status, Alcohol intake frequency, Smoking status, BMI, Number of days per week of moderate physical activity, Occupation (job code), Job involves shift work, Job involved shift work, Working hours per week
		Workplace very hot,	MW	Same as above
		Workplace very cold,	MW	Same as above
		Workplace very dusty,	MW	Same as above
		Workplace full of chemicals or other fumes,	MW	Same as above
		Workplace had a lot of cigarette smoking from people smoking,	MW	Same as above

		Work/Job satisfaction,	MW	Same as above
		Happiness,	MW	Same as above
		Family relationship satisfaction,	MW	Same as above
		Health satisfaction	MW	Same as above
III	Generalized Linear Model (Ordinal Logistic Regression) (Table 8)	Workplace very noisy, Workplace very hot, Workplace very cold, Workplace very dusty, Workplace full of chemicals or other fumes, Workplace had a lot of cigarette smoking from people smoking, Work/ Job satisfaction, Happiness, Family relationship satisfaction, Health satisfaction	MW	Age, Sex, Educational qualification, Ethnic group, Socio-economic status, Alcohol intake frequency, Smoking status, BMI, Number of days per week of moderate physical activity, Occupation (job code), Job involves shift work, Job involved shift work, Working hours per week

MW = Maximum workload

2.6 Missing data

For documenting missing data, a specific code number '999' were used in the dataset initially. All the cases in any variable that specified as '999' were recoded as missing data. The number of missing data in most of the predictor variables was very high and the numbers of missing data in each variable has been reported below in a table (Table 4). Specially, all the variables regarding physical aspects of workplace environment had huge numbers of missing data. Highest number of missing data was noticed for a co-variate – current employment status. The other two co-variates named job involves shift work and job involved shift work also had large number of missing values. Considering the high number of missing data of all used variables, the method of multiple imputation was chosen and used to correct all the missing data. For this purpose, SPSS software version 22 was used and the multiple imputation was run from the analyze option of the software. The number for imputation was set at five. After completion of the imputation process the number of data multiplies five times and a new dataset has been automatically created. Later, the newly created dataset was used for all kind of analysis.

Table 4: Amount of missing data in different variables

Name of the variable	Number of Missing data
Predictor variables	
1. Workplace very noisy	56,895
2. Workplace very cold	57,128
3. Workplace very hot	57,086
4. Workplace very dusty	57,239
5. Work place full of chemicals or other fumes	57,348
6. Workplace had a lot of cigarette smoking from other people smoking	57,150

7. Work/Job satisfaction	23,457
8. Happiness	736
9. Family relationship satisfaction	1162
10. Health satisfaction	732
Covariates	
1. Ethnic background	578
2. Townsend deprivation index (TDI)	95
3. BMI	278
4. Alcohol intake frequency	298
5. Smoking status	540
6. Number of days per week of moderate physical activity	210
7. Job involved shift work	56,738
8. Job involves shift work	34,600
9. Current employment status	77,008
12. Job code	9,137
13. Work hours per week	72,398

BMI = Body mass index

The main condition for using multiple imputation is that data should be missing at random (MAR). In UK Biobank Cohort study, participants had many options for each question to choose the desired and appropriate answer from the available options. According to that, every variable should have any of the either answer including options - do not know and prefer not to answer. But, in the used dataset large number of values were missing as stated in table 5 and they were random for which no specific cause was found. It was also not possible to extract or split the desired data that had only valid cases as they vary from each other in different variables. Considering all these, to minimize the biases, multiple imputation technique was used to correct the missing data.

2.7 Ethical consideration

Ethical permission was taken from the 'North West - Haydock Research Ethics Committee' for using UK Biobank data and this committee is a part of health research authority, NHS, UK. This study is a part of an ongoing project under Neuroscience department of Uppsala University and also having the ethical permission from the local research authority (Dnr 2017/98).

3 Results

This study investigated the association between different aspects of workplace environments and general well-being with maximum workload among middle and old aged working people. From the baseline assessment study of UK biobank, a total of 77,781 people of 39 to 72 years aged participants were drawn

for all types of statistical analyses where different lifestyle and health related information about them were also used as different variables.

3.1 Study population characteristics

All the percentages with frequencies and mean values with standard deviation for all the variables mentioned in this part has been derived from the original data. In total, the study included 77,960 participants consisting of more number of female (54.5%) compared to male (45.5%) and their mean age was 56.8 years old with a standard deviation of +8.11. Including age of the study group, other continuous variables of the study were used unchanged from the initial data and those were – BMI and Townsend deprivation index (TDI). Afterwards, to give a more detailed descriptive characteristic of the participants demography and health and lifestyle, the mean value of above mentioned variables with the standard deviation has been presented (Table 5). The mean BMI of the participants was 27.39 kg/m^2 which indicate the condition 'overweight' according to the BMI classification (84) and +4.79 was the observed standard error (SD). The average of Townsend deprivation index of the study population was -1.05 with the standard deviation of +2.99. Such a negative score of TDI represents affluence of the study population. Majority of them belongs to the major ethnic group (White) that consisted of 90.9% of the study population and 9.1% of participants belongs to the minor ethnic group (others – Black, Asian, Mixed, Others). About 65.3% of this population do not have college or university level education and 34.7% of the population completed their college education or have gained qualification more than this level (professional qualifications). Around 0.1% of the study people have history of chronic rheumatic heart disease. Similarly, 0.1% participant have genetic disease. Almost 34.5% of the study population found as previous smoker and 9.5% were current smokers and around 20.3% of them are daily alcohol drinkers. The pooled mean values and frequencies with percentages of participants characteristic variables from imputed dataset are also presented below in the same table at a different column (Table 5). After multiple imputation, all variables found to be have similar or almost near to similar percentages and mean values from the original data.

Table 5: Baseline characteristics of the participants

	Original data		**Pooled data**	
Characteristics	**Mean ± Standard deviation (SD)**	**Frequencies (Percentages) n (%)**	**Mean**	**Frequencies (Percentage) n (%)**
Demographics				
1.Age (years)	56.8 ± 8.11	-	56.8	-
2.Sex				

5 Female	-	42,494 (54.5%)	-	42,494 (54.5%)
6 Male		35,466 (45.5%)		35,466 (45.5%)
3.Ethnic group				
a. Major ethnic group (White)	-	70,303 (90.9%)	-	70,816.6 (90.8%)
b. Minor ethnic group (Others)		7,079 (9.1%)		7,143.4 (9.2%)
4.Townsend deprivation index	-1.05 ± 2.99	-	-1.05	-
5.Qualifications (at least have college/ university level education or more)	-		-	
a. No		50,887 (65.3%)		50,887 (65.3%)
b. Yes		27,073 (34.7%)		27,073 (34.7%)
Health and lifestyle				
1.Smoking status				
a. Never	-	43,064 (55.6%)	-	43,283.6 (55.6%)
b. Previous		26,932 (34.8%)		27,202.2 (34.8%)
c. Current		7,424 (9.6%)		7,474.2 (9.6%)
2.Alcohol intake frequency				
a. Never		6,584 (8.5%)		6,605.8 (8.5%)
b. Daily/almost daily		15,858 (20.4%)		15,880.4 (12.6%)
c. 3/4 times a week	-	17,411 (22.3%)	-	17,463.6 (11.4%)
d. 1/2 times a week		19,296 (24.8%)		19,367.8 (24.9%)
e. 1-3 times/month		8,774 (11.3%)		8851.4 (22.3%)
f. Special occasions only		9,739 (12.5%)		9,791 (20.3%)
3.BMI	27.39 ± 4.79	-	27.4	-
4. Number of days per week of moderate physical activity				
a. 0 day		8,791 (11.5%)		9,004.2 (11.5%)
b. 1 day		5,837 (7.9%)		6,223.2 (7.9%)
c. 2 days	-	10,796 (14.6%)	-	11,385 (14.6%)
d. 3 days		11,173 (15.3%)		11,918.8 (15.3%)
				8,318.4 (10.7%)
e. 4 days		7,554 (10.7%)		12,099 (15.5%)
f. 5 days		11,441 (15.5%)		4,638.6 (6%)
g. 6 days		4,151 (6%)		14,372.8 (18.5%)
h. 7 days		14,085 (18.5%)		
5.Chronic rheumatic heart disease				
a. No	-	77,884 (99.9%)	-	77,884 (99.9%)
b. Yes		76 (0.1%)		76 (0.1%)
6.Genetic disease				
a. No	-	77,857 (99.9%)	-	77,857 (99.9%)
b. Yes		103 (0.1%)		103 (0.1%)

BMI – Body mass index

Similarly, mean value with standard deviation for the continuous variable working hours per week and frequencies with percentages for rest of the occupational characteristics has been shown below in a table for both values from original dataset and pooled values from imputed dataset (Table 6). At first, values from original dataset has been described in this part. Around 9.5% people were involved in jobs that included shift works. (Table 6). The mean of their working hours were 40.67 hours per week with an observed SD of +9.29. The pooled mean and frequencies from imputed dataset are also presented below in the same table (Table 6) which is, overall, almost similar to the original frequencies and mean.. But,

few variables found to be have slightly different percentages from the original data. For instance, in the variable job code, different occupation percentages are slightly different from the original values. After the application of imputation method, the variable named job involves shift work included three categories where 77.2% population never did shift work. On the other hand, 15.9% study participants did shift works usually or always and 6.8% found to did shift work sometimes in their workplace. Also, on the other variable named job involved shift work around 84.6% of study population reported about never doing shift works while about 15.3% people from the study group reported to had shift works. (Table 6)

Table 6: Occupational characteristics of the participants

	Original data		Pooled data	
Occupational characteristics	**Mean ± Standard deviation (SD)**	**Frequencies (percentages) n (%)**	**Mean**	**Frequencies (percentages) n (%)**
1.Job code				
a. Managers & senior officials	-	12,207 (17.7%)	-	13,017.6 (16.7%)
b. Professional occupations		16,084 (23.4%)		17,318.2 (22.2%)
c. Associate professional & technical professions		11,444 (16.6%)		13,051.2 (16.7%)
d. Administrative and secretarial occupations		11,432 (16.6%)		13,168.6 (16.9%)
e. Skilled trade occupations		4,896 (7.1%)		6,413.2 (8.2%)
f. Personal service occupations		4,078 (5.9%)		5,172.4 (6.6%)
g. Sales and customer service occupations		2331 (3.4%)		2,996 (3.8%)
h. Process, plant and machine operatives		3,004 (4.4%)		3,331.2 (4.2%)
i. Elementary occupations		3,347 (4.9%)		3,491.6 (4.4%)
a.				
3.Working hours (per week)				
	40.67 ± 9.29	-	40.4	-
4.Job involves shift work				
a. Never	-	35,929 (82.9%)	-	60,205.4 (77.2%)
b. Sometimes		3,256 (7.5%)		5,344 (6.8%)
c. Usually/Always		4,175 (9.6%)		12,410.6 (15.9%)
5.Job involved shift work				
a. No	-	18,284 (86.2%)	-	65,990 (84.6%)
b. Yes		2,938 (13.8%)		11,970 (15.3%)

Frequencies with valid percentages of different predictor variables have been presented in the following table (Table 7). Both original and imputed percentages for all predictors have been mentioned in the same table. 45.2% people reported them as exposed to noise in their workplace while 54.8% were reported as non-exposed to noise. On the other hand, 70.9% participants were not exposed to cold in their

workplace and 29.1% people were exposed to cold temperature in workplace. Among the participants, 57% were found to have no exposure of hot temperature in their work places, but 43% were counted to have hot exposures in the work environment. The percentage of population of workplace dust exposure were 25% and 75% were not exposed to dust. 15.7% were exposed to chemicals and other fumes and 84.3% were not exposed to similar things in the workplace. The percentage of passive smoking exposure was 47.1% while 52.9% had no exposure to passive smoking. 89.9% participants were satisfied with their jobs and 10.1% were not satisfied with their jobs. Around 95.1% participants reported themselves as happy, while 4.9% people reported who were not happy. 93.2% people were satisfied with their family relationship and on the other hand, 6.8% participants mentioned no satisfaction to family relationship. Also, 86.3% people were satisfied with their health and 13.7% found to have no health satisfaction (Table 7).

Table 7: Frequencies for different aspects of workplace environment and general well-being

	Original data	**Pooled data**
Predictor variables	**Frequencies (Percentages) n (%)**	**Frequencies (Percentage) n (%)**
Physical workplace environment		
1.Workplace very noisy		
No	11,546 (54.8%)	40,424 (51.9%)
Yes	9,519 (45.2%)	37,536 (48.1%)
2.Workplace very cold		
No	14,764 (70.9%)	51,910 (66.6%)
Yes	6,068 (29.1%)	26,050 (33.4%)
3.Workplace very hot		
No	11,896 (57%)	42,013.8 (53.9%)
Yes	8,978 (43%)	35,946.2 (46.1%)
4.Workplace very dusty		
No	15,533 (75%)	55,755.2 (71.5%)
Yes	5,188 (25%)	22,204.8 (28.5%)
5.Workplace full of chemicals or other fumes		
No	17,369 (84.3%)	64,080.4 (82.2%)
Yes	3,243 (15.7%)	13,879.6 (17.8%)
6. Workplace had a lot of cigarette smoking from people smoking		
No	11,007 (52.9%)	39,527.4 (50.7%)
Yes	9,803 (47.1%)	38,432.6 (49.3%)
Psychosocial workplace environment and General well-being		
1.Work/Job satisfaction		
No	5,489 (10.1%)	7,358 (9.4%)
Yes	49,014 (89.9%)	70,602 (90.6%)
2. Happiness		
No	3,805 (4.9%)	3,876.4 (4.98%%)
Yes	73,419 (95.1%)	74,083.6 (95.02%)
3. Family relationship satisfaction		
No	5,212 (6.8%)	5,349.6 (6.9%)

Yes	71,586 (93.2%)	72,610.4 (93.1%)
4. Health satisfaction		
No	10,551 (13.7%)	10,717.8 (13.7%)
Yes	66,677 (86.3%)	67242.2 (86.3%)

3.2 Crude analysis

At first, in model I, ordinal logistic regression has been done among all the predictor variables individually with the outcome variable (maximum workload). The variables related to the physical aspects of workplace environment and results have been shown below from pooled analysis. Overall significance was found for four variables except for the two variables that are - Workplace very noisy and Workplace had a lot of cigarette smoking from other people smoking. The estimate (B) for the first variable was 0.013 with a 95% confidence interval (95% CI) of -0.100, 0.127. On the other hand, the other variable had an estimate of -0.005 where 95% CI was -0.094, -0.085. The effect sizes varied, and only the variable 'workplace very noisy' showed a positive effect (Estimates = 0.013) while rest of the variables regarding physical aspects of work environment showed negative effect. However, physical environmental aspects – very hot, very dusty and full of chemicals or fumes, very noisy, very cold, smoking from other people were found to have very small effect sizes. The variable named 'Workplace had a lot of cigarette smoking from people smoking' had an estimate of 0.005, which is extremely low.

For the variables related to psychosocial aspect of work environment and general well-being, three variables – Work/job satisfaction, Happiness and Health satisfaction showed statistically significant result. But, except work/job satisfaction variable (B = 0.346), all other variables of psychosocial aspect of workplace environment and general well-being were found to have negative estimate values. In the univariate analysis, Work/job satisfaction had estimate value 0.346 and 95% CI is 0.287, 0.405. For happiness, estimate value of -0.079 yielded with 95% CI -0.140, -0.018. Similarly, health satisfaction also showed a negative estimate value of -0.786 where 95% CI is -0.825, -0.748. Effect sizes were different for each of them and ranges from very small to small size (Table 8).

In model I, analysis of all co-variates and maximum workload were also recorded which has been presented below on a different table (Table 8). On the crude analysis of all co-variates with maximum workload, co-variate named – job involves shift work did not show any statistically significant result and all other co-variates were found to have statistically significant results. On the other hand, people who never do shift works showed 0.137 estimate value and the noted 95% CI is -1.111, 1.386. The B-value for participants who sometimes do shift works is 0.262 where the 95% CI is -0.878, 1.403. That means current employment status or job that involves shift work is not related to low maximum workload. However, people who never drink alcohol showed very little effect of having low maximum workload compared to people who drink at different ranges. Negative estimate levels have been recorded for three different occupational groups, namely - administrative and secretarial occupations, personal service

occupations and sales and customer service occupations. Participants involved in these professions having negative estimate value means they have more chance to have lower maximum workload. Other co-variates that were also found to have negative estimate values and same possible outcome of cardiovascular diseases are – Sex, age, TDI, ethnic group, educational qualification, BMI, smoking status and job involved shift work. (Table 8)

Table 8: Crude analysis of all predictor variables and all co-variates with maximum workload (Model I)

Predictor variables	Estimate (B)	95% CI Lower	95% CI Upper	Significance
Physical aspects of workplace environment				
Workplace very noisy (Yes → Ref.)	0.013	-0.100	0.127	0.774
Workplace very cold (Yes → Ref.)	-0.080	-0.147	-0.013	0.025
Workplace very hot (Yes → Ref.)	-0.122	-0.175	-0.069	0.001
Workplace very dusty (Yes → Ref.)	-0.137	-0.197	-0.076	0.001
Workplace full of chemicals or other fumes (Yes → Ref.)	-0.285	-0.379	-0.191	<0.001
Workplace had a lot of cigarette smoke from other people smoking (Yes → Ref.)	-0.005	-0.094	-0.085	0.901
Psychosocial aspect of workplace environment and General well-being				
Work/Job satisfaction (Yes → Ref.)	0.346	0.287	0.405	<0.001
Happiness (Yes → Ref.)	-0.079	-0.140	-0.018	0.012
Family relationship satisfaction (Yes → Ref.)	-0.005	-0.056	0.046	0.838
Health satisfaction (Yes → Ref.)	-0.786	-0.825	-0.748	<0.001
Covariates				
1. Demographics				
Sex (Male → Ref.)	-2.364	-2.395	-2.333	<0.001
Age	-0.087	-0.089	-0.085	<0.001
Townsend deprivation index (TDI)	-0.026	-0.030	-0.021	<0.001
Ethnic group (Major ethnic group → Ref.)	-0.219	-0.262	-0.175	<0.001
Educational qualification (Have ≥ college or university level education → Ref.)	-0.491	-0.517	-0.465	<0.001
2. Health & Lifestyle				
BMI	-0.018	-0.021	-0.015	<0.001
Alcohol intake frequency (Special occasions only → Ref.)				
Never	-0.091	-0.146	-0.036	0.001
Daily/Almost daily	0.716	0.672	0.760	<0.001
3-4 times/week	0.770	0.727	0.813	<0.001
Once/twice a week	0.616	0.573	0.658	<0.001
1-3 times/month	0.407	0.356	0.457	<0.001
Smoking status (Current smoker → Ref.)				
Never	-0.139	-0.183	-0.094	<0.001
Previous	-0.116	-0.163	-0.070	<0.001

Number of days of moderate activity per week (7 days → Ref.)				
	0 day	-0.051	-0.098	-0.004	0.035
	1 day	0.241	0.187	0.294	<0.001
	2 days	0.165	0.122	0.208	<0.001
	3 days	0.095	0.052	0.138	<0.001
	4 days	0.105	0.057	0.154	<0.001
	5 days	0.183	0.141	0.226	<0.001
	6 days	0.224	0.158	0.289	<0.001
3. Occupational				
Job involves shift work (Usually/Always → Ref.)				
Never		0.137	-1.111	1.386	0.775
Sometimes		0.262	-0.878	1.403	0.559
Job involved shift work (Yes → Ref.)		-0.322	-0.408	-0.235	<0.001
Job code (Elementary occupations → Ref.)				
- Managers & senior officials		0.928	0.859	0.997	<0.001
- Professional occupations		0.493	0.426	0.560	<0.001
- Associate professional & technical professions		0.404	0.334	0.473	<0.001
- Administrative and secretarial occupations		-0.191	-0.258	-0.123	<0.001
- Skilled trade occupations		0.677	0.596	0.758	<0.001
- Personal service occupations		-0.259	-0.345	-0.174	<0.001
- Sales and customer service occupations		-0.396	-0.485	-0.308	<0.001
- Process, plant and machine operatives		0.690	0.596	0.784	<0.001
Work hours per week		0.019	0.015	0.023	<0.001

CI = Confidence interval, Ref. = Reference group

3.3 Adjusted analysis

Moreover, in model II, the pooled analysis by ordinal logistic regression among physical aspects of workplace environment variables showed significant values for five variables after adjusted with all co-variates. Other variable –Workplace had a lot of cigarette smoking from other people smoking has been found to be not statistically significant**.** The estimate values for this variable was 0.066 with 95% CI = -0.031, 0.163. Furthermore, positive effect sizes were found for all the variables of physical aspects of workplace environment, but the effect sizes ranged from very small to small. Among the variables related to psychosocial aspects of workplace environment and general well-being of an individual overall significant values were found for all four variables after adjusting with all co-variates. All of them have negative estimate sizes and ranges from very small to large effect sizes. That means when goes from yes to no for each variable, the non-exposed persons will have more chance of having low maximum workload. The effect size for health satisfaction is quite large with an estimate value of -0.884 and 95% CI is -0.927, -0.841. (Table 9)

In model III, when the predictor variables were adjusted with different co-variates all together, only the variable Health showed a significant association with the outcome. For health satisfaction, the estimate value is -0.866, 95% CI = -0.910, -0.823. However, positive estimate values seen for only three variables which are, namely Workplace very noisy (B = 0.049), Workplace very cold (B= 0.066) and Workplace

very dusty (B = 0.073 Though the variables named workplace very hot and happiness showed negative estimate values, but the 95% CI were not statistically significant in either cases (Table 9).

Table 9: Adjusted analysis of all predictor variables, all co-variates and Maximum workload (Model II and III)

Predictor variables	Model II				Model III			
		95% CI				95% CI		
	Estimate (B)	Lower	Upper	Significance	Estimate (B)	Lower	Upper	Significance
Physical aspects of workplace environment								
Workplace very noisy (Yes → Ref.)	0.116	0.004	0.228	0.045	0.049	-0.092	0.191	0.404
Workplace very cold (Yes → Ref.)	0.140	0.083	0.197	<0.001	0.066	-0.027	0.160	0.133
Workplace very hot (Yes → Ref.)	0.088	0.044	0.132	0.001	-0.004	-0.046	0.038	0.845
Workplace very dusty (Yes → Ref.)	0.175	0.130	0.220	<0.001	0.073	-0.002	0.148	0.056
Workplace full of chemicals or other fumes (Yes → Ref.)	0.196	0.098	0.294	0003	0.102	-0.004	0.207	0.056
Workplace had a lot of cigarette smoking from people smoking (Yes → Ref.)	0.066	-0.031	0.163	0.140	0.032	-0.067	0.131	0.447
Psychosocial aspect of workplace environment and General well-being								
Work/Job satisfaction (Yes → Ref.)	-0.096	-0.159	-0.032	0.005	0.044	-0.033	0.121	0.241
Happiness (Yes → Ref.)	-0.302	-0.370	-0.235	<0.001	-0.050	-0.130	0.029	0.210
Family relationship satisfaction (Yes → Ref.)	-0.169	-0.220	-0.118	<0.001	0.001	-0.053	0.056	0.967
Health satisfaction (Yes → Ref.)	-0.884	-0.927	-0.841	<0.001	-0.866	-0.910	-0.823	<0.001

Ref. = Reference group, CI = Confidence interval

4 Discussion

4.1 Results summary

In the findings from the crude analysis derived both from the original and pooled data analysis, a statistical significant association has been found. This indicates a positive association of different aspects of workplace environment and general well-being with having possible lower maximum workload,. Both physical and psychosocial aspects of the workplace have negative effect on maximum workload among the exposed workers. Also, few conditions of the workplace such as – workplace very noisy, workplace very cold, workplace had a lot of cigarette smoking from people smoking and family relationship were

found to have no statistically significant results with maximum workload. However, the variable named 'workplace had a lot of cigarette smoke from other people smoking' had a negative estimate value of -0.005 (B = -0.005) and that is very small effect size. Moreover, people who never drink alcohol showed a negative association (B = -0.091) with maximum workload in the crude analysis which means a possibility of having low maximum workload. The other factor named job involves shift work has no statistically significant result in pooled crude analysis and contains positive estimate values. However, in the crude analysis of the original data showed that job never involves shift work has a statistically significant result with negative estimate value which indicates the possibility of low maximum workload. Working hours was found to have no association with maximum workload.

Model II was created to see the individual effect of different aspects of workplace environment and general well-being with maximum workload when adjusted for different covariates like – demographic factors, health and life-styles factors and occupational factors of the participants. All four predictors from psychosocial aspect of workplace and general well-being had negative association with maximum workload. But, all the physical aspects related predictors showed the opposite result though they were statistically significant, and all had positive estimate values.

Model III was conducted to investigate the combined effects of different aspects of workplace environment and general well-being with maximum workload when adjusted with demographic, health and life-style and occupational related factors all together. All predictor variables lose their previous effects and only one predictor variable found to have statistically significant result. Only health satisfaction had negative estimate value (B = -0.866, 95% CI -0.910, -0.823), which means when going from yes to no, there is more chance of having low maximum workload. The effect size is large enough to establish this association more strongly. Other remaining predictor variables showed not statistically significant results in this model when adjusted for all co-variates collectively.

Results dynamically changed from model II to model III when all predictor variables were adjusted together with all covariates at a time. The results that were significant in model II became not statistically significant in model III. In model III, all predictors and all covariates were adjusted together to see the combined effect of predictors rather than individual effect in model II. This adjustment may reduce the underlying variability in the data so that more precise comparisons can be made. Also, depending on large sample size, it is possible to correct for multiple covariates without incurring in the risk of over-adjustment. Moreover, the health satisfaction was found to be significant in all tested model, so the possibility can be rule out that the variable was only significant due to overfitting issues.

4.2 Comparison to other studies

Health satisfaction had strong statistical significant result in favor of the research question in all types of analysis, both in crude analysis and in two adjusted analytical models. This finding also matches the

results from many other previous studies. Similarly, positive psychosocial well-being and life satisfaction exerts strong protective effect for CVD which has been mentioned in many other studies (57,85). In different studies, other psychosocial factors related to workplace or general well-being were also found to have an association with cardiovascular morbidity and mortality (14,34,35). However, in the current study amongst all psychosocial factors, only health satisfaction was significantly associated to the maximum workload after adjusting for different co-variates.

Physical factors from workplace environment were also established to have effect on CVD risk and mortality in different studies either individually or collectively with other factors. Exposure to tobacco smoke that means passive smoking, along with chemical exposure has been detected to have strong and positive association with increased risk of CVD (38). In the current study, both crude and adjusted models did not show such kind of association. For example, in all analysis, workplace had a lot of cigarette smoking from other people smoking had no statistically significant result which did not match the previous studies. But, showed a negative association in crude analysis which disappeared on adjusted models and the negative estimate value from crude analysis was not significant.

Exposure to noise in workplace had statistical significant result only during the analysis in model II and became not statistically significant in other two models (model I and III). However, a strong association of noise exposure with higher risk of CVD has been established by multiple researchers in multiple studies (39–42). A cohort study in Korea among male workers reported that noise exposure which was chronic can independently increase the blood pressure (42). Noise and heat exposure among workers in the workplace were collectively found to be associated with different CVDs in another study (50). On an epidemiological review, both short-term and long-term adverse effects from heat exposure was mentioned, which also included the relationship between chronic heat exposure and cardiovascular diseases (48). Another study established that extremes of temperature (either heat or cold) in the workplace were linked to an increased risk of acute cardiovascular events, specially in workers who had pre-existing CVD (8). Current study found positive relations between exposure to extreme of temperature either very hot or very cold and maximum workload when very hot or very cold temperatures in workplace were adjusted for all co-variates individually in model II and most of them were statistically significant. But, the relation became changed in model III, while all predictors were adjusted together for all co-variates and both the predictors very hot and very cold temperatures in workplace had negative relation with maximum workload and that was not statistically significant results.

Moreover, workers exposure to chemicals and other fumes in their workplace had a positive association with maximum workload and that was significant in first adjusted model (model II) (95% CI 0.098, 0.294) which in second adjusted model (model III) was no longer significant (95% CI -0.004, 0.207). It means participants exposed to chemical and other fume in the workplace are related to have higher maximum workload and thus assumed low risk of CVD. But, an possible increased risk of CVD with

chronic exposure by different chemical have been mentioned in a study (45). The difference between results of current study and the previous studies may be due to different reasons like - the assessment method, degree of exposure of chemicals among the workers and may also because of the way of reporting by the workers. Also, the variation may be related to the different occupational category as workers of every occupation are not exposed to or less exposed to the chemical and fume exposure in the workplace.

4.3 Strengths

A cross-sectional study is a good epidemiological study to predict an association between exposures or risk factors and outcome. The main strength of the current study is the large sample size. The UK Biobank Cohort study, a large prospective study started in the year of 2006 and the baseline assessment continued for a period of five long years up to the year of 2010 among 500,000 volunteer population all over the United Kingdom. For the current study, 77,781 participants were extracted from the UK Biobank Cohort study population depending on different inclusion and exclusion criteria's that has been mentioned in the method section and this group of population represents a large sample size. Such a large size of study sample is helpful for any researcher to indicate a more precise result as well as also useful for making fruitful conclusions. The internal validity of the UK Biobank cohort study is also very strong as it was conducted under the guidance of trained and experienced health professionals. On the other hand, maximum workload was measured during the ECG stress test. ECG stress test is a non-invasive, relatively less expensive, reliable and most widely used screening test without having any exposure of radiation to the participant. This test was conducted under the guidance and supervision of trained technician of the UK Biobank study during the baseline assessment for measurement of the outcome variable (Maximum workload). The protocols and procedures were strictly followed by the trained technicians to maintain the accuracy of the test and generated results. An ECG test during exercise is able to create a trustworthy and consistent outcome (86). The CASE software was used to generate the formula for measuring outcome variable (maximum workload), is a more convenient system for assessing cardiac function during exercise and diagnostic confidence is also great (80). The other strength of the study is the number of used predictor variables. Different factors related to both physical and psychosocial aspects of workplace environment along with general well-being that are impacting on work environment had been considered for this study. Moreover, many variables have been taken into consideration for the current study and both physical aspects and psychosocial aspects of workplace environment and general well-being had been the focus in this study. The number of confounding variables considered were also high and results were adjusted for all of them.

4.4 Limitations

However, this present study also had some limitations. As it is a cross-sectional study, the study has, of course, all the weaknesses of a cross-sectional study. Data for each participant were recorded only once during the baseline assessment and therefore, it is difficult to assess the temporal association between a risk factor and an outcome in a cross-sectional study. Firstly, the information about the participants regarding individuals background detail about socio-economic status, other demographic, lifestyle and health related conditions, employment status, family history and histories of different health or medical conditions and medications were recorded by using a touch screen questionnaire and used only one question for each variable. All these conditions and also other conditions related to workplace environment were self-reported and self-administered by the participants in the questionnaire. More detailed information about these aspects related to participants were collected by trained health staffs through verbal interviews and were also self-reported by the participating population. Secondly, based on the self-reported and self-administered information, there is no way to confirm whether the participants who reported about certain exposure or exposures about the different aspects of workplace condition, were really exposed or not. On the other hand, questionnaire used in the baseline assessment was one-question based for each predictor variable. So, assessment of the true exposure or amount of exposure was unknown, and questionnaire was not enough or adequate to detect the level or degree of each exposure. Participants themselves are the only source who could guarantee about truthfulness and reliability of the data regarding ratification of different exposures in their current or previous workplace. Information bias is a potentiality that could arise due to lack of assessment of differences in exposure among the participants. There is also a chance of misreporting and over-reporting about different exposures in workplace described by the study participants and this situation could lead to an overestimation or underestimation of the risks among the participants. Thirdly, the current employment status of most of the study population was retired (92.8%) which could be also counted as a weakness of the current study. As the duration of their retirement period is unknown, there is a greater probability of recall bias among this group of study population. Fourthly, disease status of the study subjects was also unknown. Only people with congenital heart disease and chronic rheumatic heart disease were excluded from the study. But, study subjects with existing other cardiovascular disease or condition or with related other disease condition were unexplored and were not taken into consideration in this current study. More detailed information about all the used parameters that is measured or assumed from different factors, could also be related to some unpredictable and undesirable outcome which is missing. However, many important confounders have been included in the study, still there is a chance of confounding bias because of lack of information and this bias may be responsible for generating deceitful results. All the confounding factors were self-reported by the study participants and might be responsible for masking a form of information bias. Finally, the percentage of missing data for each predictor variable cannot be overlooked at all. Despite missing data has been corrected by using the method of multiple imputation, a

large number of missing data were present in most of the predictor variables in the original dataset that were used in the frequency and mean tables in this study before running the imputation method.

4.5 Generalizability and public health impact of the result

Cardiovascular diseases continues to be the leading cause of morbidity as well as mortality (2). Working conditions are recognized as one of the additional risk factor for CVD. The effect of different aspects of workplace environment and general well-being on the vascular health is also different. Consideration of occupational environment and well-being from multiple perspectives are important for the better prediction and assessment of occupational impacts on the individual workers health (87). In most studies, different physical and psychosocial aspects of workplace environment had an established relationship with higher risk of CVD, especially in working group with chronic exposure or in whom who had pre-existing CVD. Because of certain occupational hazardous exposures in the workplace, the workers are more vulnerable than general population. But, this study found more close relation of a general well-being factor rather than different aspects of workplace environment with maximum workload and thus risk of CVD in working population. This finding is vital as it establishes the importance of general well-being of a worker and signifies that worker's poor satisfaction in general could affect negatively both on his work and also on his general health. It clearly shows the need for creating different promotive and preventive interventions in workplace to promote, support and maintain a worker's overall satisfaction. In addition to this, these results highlighted the needs for further research to strengthen this relation and to investigate more aspects of workplace environment and well-being related factors that could have positive or negative association with CVD and also with other health related outcomes. Future studies should comprise of larger working cohort with prospective follow-up studies with proper information about different exposure and should also include appropriate measures of calculating the amount of risk. From epidemiological angle, current study results can be taken into consideration for comparison with future results. Moreover, a healthier working force therefore can contribute towards better economy and development of a country and will also be helpful in reducing morbidity and mortality from not only CVD but also from other workplace related diseases. Disability adjusted life years (DALYs) and Years lived with disability (YLDs) derived from CVD can also be controlled.

The study includes a large sample size and the statistically significant result regarding health satisfaction of a worker remained same in all models of analysis, even after adjusting for all co-variates. So, it can be easily generalizable to working population in general, at least in developed or industrialized countries having same background as UK. Somehow, the health of workers is still ignored and of less importance in middle and low-income countries that indicates a clear research gap in those countries. Overall, if all the goals are fulfilled, we can facilitate the way of achieving the sustainable development goals (SDGs), specially goal number 3 which focuses on ensuring and promoting healthy life.

5 Conclusion

Environment is changing everywhere with an increasing frequency and intensity, also affecting different work places. Somehow, the potential influence or effect of different aspects of workplace environment and general well-being are being underestimated in some extent, which may be due to underreporting or underestimating of the exposures and illnesses, and most importantly due to lack of awareness about the risk of work-related problems and impact of work environment and well-being on employees' health. Though other variables found to have statistically significant results in crude analysis and first adjusted model, all disappeared and became not statistically significant in the last adjusted model where all variables were adjusted for all covariates. Both physical and psychosocial aspect of workplace environment were found to have no statistically significant association with maximum workload. More evidence is required from future studies as the result may vary due to gender, occupation and may be due to difference in amount of exposures. The study findings from the different models were in line with previous studies conducted in different countries. Positive association between low health satisfaction and low maximum workload assumed to contribute towards higher risk of CVD among the participated employees created public health concern and future studies are needed to support this outcome. Further studies may include different study designs such as – longitudinal studies can be done to establish the direct association with risk of cardiovascular diseases or case-control studies may help to compare the results between the exposed and non-exposed groups. Proper guidelines for early detection and prevention of CVD among employees is very much needed with proper and continuous surveillance of the risk factors of CVD. To reduce the challenges and injuries and also to promote the overall health and well-being of the workers in their workplaces, different preventive measures should be taken. Such measures and strategies will help to reduce not only the risk of CVD and other NCDs, but also to avoid the risk of other workplace related health outcomes among working population.

Acknowledgement

I want to convey my warm regards and deepest gratitude to Professor Helgi Schiöth from Department of Neuroscience, Uppsala University for giving me the golden opportunity to conduct the interesting study and also for his valuable guidance. I want to express my special thanks to Dr. Gaia Olivo for the overall guidance, support and statistical training. I would also like to express thanks to Erik Olsson for all the meeting sessions and valuable feedback that really helped me to improve my overall work. All the supports were extremely precious for my thesis project which showed me the right direction and helped to improve both my theoretical and practical knowledge. Finally, I am grateful to my beloved family,

friends and colleagues who supported me greatly and encouraged me to finish the project within such a limited time frame.

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