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ABSTRACT

Evidence on the relation between the life stressors and cardiovascular health of aging workers has been scarce. The aim of this thesis was to examine the association of work-related factors and private life stressors with ambulatory blood pressure and large arterial stiffness. The association between work-related psychosocial stressors and variation in home blood pressure during the working week, and the effects of the retirement transition on ambulatory blood pressure, were also studied.

The data were from three Finnish population-based cohort studies: the Finnish Retirement and Aging study, the DIetary, Lifestyle, and Genetic determinants of Obesity and Metabolic syndrome study and the Health 2000 study. Work- and stress-related exposures were measured using survey instruments and the cardiovascular health outcomes were ambulatory blood pressure, carotid-to-femoral pulse wave velocity and home blood pressure. Analysis of variance, generalized linear models and linear regression analysis were the main statistical methods used.

Among the aging workers in the study, shift work was related to higher awake systolic blood pressure values and nocturnal diastolic blood pressure dipping than regular day work. In addition, high, compared to low, job demands were associated with less nocturnal blood pressure dipping. Workers with recent serious life events or financial difficulties had a higher carotid-to-femoral pulse wave velocity than their counterparts. High job strain and high job demands, as opposed to low job strain and low job demands, were associated with a decrease in blood pressure from weekdays to weekend days. Retirement transition was associated with unfavorable changes in asleep systolic blood pressure. Shift work was related to unfavorable changes in ambulatory blood pressure during the retirement transition.

In conclusion, high job strain, high job demands, shift work, serious life events and financial difficulties associated with cardiovascular health indicators. In addition, retirement transition seemed to have a negative, although transient, impact on systolic ambulatory blood pressure. Work-related factors, life stressors and the retirement transition should be taken account when promoting cardiovascular health.

KEYWORDS: Aging workers, ambulatory blood pressure, large arterial stiffness, blood pressure dipping, home blood pressure, life stressors, office blood pressure, work-related psychosocial stressors

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TIIVISTELMÄ

Tutkimustieto elämän stressitekijöiden ja sydänterveyden yhteydestä ikääntyvillä työntekijöillä on vähäistä. Tämän väitöskirjan tavoitteena oli tutkia, miten työhön ja elämään liittyvät stressitekijät ovat yhteydessä vuorokausiverenpaineeseen ja suurten valtimoiden jäykkyyteen. Lisäksi tutkittiin työhön liittyvien psykososiaalisten tekijöiden yhteyksiä kotona mitatun verenpaineen vaihteluun työviikon aikana ja eläköitymisen vaikutuksia vuorokausiverenpaineeseen.

Tutkimuksen aineistot olivat peräisin kolmesta suomalaisesta väestöön pohjautuvasta kohorttitutkimuksesta: Finnish Retirement and Aging -, DIetary, Lifestyle, and Genetic determinants of Obesity and Metabolic syndrome - ja Terveys 2000 -tutkimuksista. Altistuminen stressitekijöille selvitettiin kyselyillä ja sydänterveyttä mitattiin vuorokausiverenpaineen, pulssiaallon nopeuden ja kotona mitatun verenpaineen avulla. Tilastollisessa analyysissä käytettiin pääasiallisesti varianssianalyysiä, yleistä lineaarimallia ja lineaarista regressioanalyysiä.

Vuorotyön tekijöillä oli korkeampi päiväaikainen systolinen verenpaine ja heidän diastolinen verenpaineensa laski nukkuessa enemmän kuin säännöllistä päivätyötä tekevillä henkilöillä. Suuria työn vaatimuksia raportoineilla työntekijöillä systolinen ja diastolinen verenpaine laskivat nukkuessa vähemmän kuin matalia työn vaatimuksia kokeneilla työntekijöillä. Edeltävänä vuonna vakavan elämän tapahtuman tai taloudellisia vaikeuksia kokeneilla työntekijöillä pulssiaallon nopeus oli korkeampi kuin muilla työntekijöillä. Korkea työstressi ja korkeat työn vaatimukset yhdistyivät verenpaineen laskuun arkipäivien ja viikonlopun välillä toisin kuin matala työstressi ja matalat työn vaatimukset. Eläköityminen oli yhteydessä nukkumisen aikaiseen systolisen verenpaineen nousuun. Vuorotyöllä oli yhteys haitallisiin muutoksiin vuorokausiverenpaineessa eläköityessä.

Työstressi, työn vaatimukset, vuorotyö, vakavat elämän tapahtumat ja taloudelliset vaikeudet olivat yhteydessä sydänterveyteen. Eläköitymisellä näyttää olevan hetkellinen negatiivinen vaikutus systoliseen vuorokausiverenpaineeseen. Työhön liittyvät tekijät, elämän stressitekijät ja eläkkeelle siirtyminen tulisi ottaa huomioon sydän- ja verisuonisairauksia torjuttaessa.

AVAINSANAT: Ikääntyvä työntekijä, vuorokausiverenpaine, isojen valtimoiden jäykkyys, verenpaineen yönaikainen lasku, kotiverenpaine, elämän stressitekijät, vastaanottopaine, työhön liittyvät psykososiaaliset stressitekijät

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Abbreviations

ABP	Ambulatory blood pressure
AIx	Augmentation Index
BMI	Body mass index
BP	Blood pressure
CI	Confidence interval
COPSOQ	Copenhagen Psychosocial Questionnaire
DBP	Diastolic blood pressure
DILGOM	DIetary, Lifestyle, and Genetic determinants of Obesity and Metabolic syndrome study
ECG	Electrocardiogram
ERI	Effort–reward imbalance
ESH	European Society of Hypertension
FIREA	Finnish Retirement and Aging study
GBD	Global Burden of Disease
GEE	Generalized estimating equations
JCQ	Job Content Questionnaire
LDL	Low-density lipoprotein
MET	Metabolic equivalent task
MVPA	Moderate-to-vigorous physical activity
NCD-RisC	Non-Communicable Disease Risk Factor Collaboration
PWV	Pulse wave velocity
SBP	Systolic blood pressure

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Karelius S, Vahtera J, Pentti J, Lindroos AS, Jousilahti P, Heinonen OJ, Stenholm S, Niiranen TJ. The relation of work-related factors with ambulatory blood pressure and nocturnal blood pressure dipping among aging workers. *International Archives of Occupational and Environmental Health*, 2020; 93(5):563-570.

II Karelius S, Vahtera J, Heinonen OJ, Niiranen TJ, Stenholm S. Association between Life Stressors and Arterial Stiffness: The Finnish Retirement and Aging Study. *Artery Research*, 2021; 27(3):129–134.

III Karelius S, Pentti J, Juhanoja E, Jula A, Koskinen S, Niiranen TJ, Stenholm S. Association of work-related psychosocial factors and day-to-day home blood pressure variation: the Finn-Home study. *Journal of Hypertension,* 2024; 42(2):337-343.

IV Karelius S, Vahtera J, Suorsa K, Heinonen OJ, Pentti J, Niiranen TJ, Stenholm S. Changes in ambulatory blood pressure during the transition to retirement. *Journal of Hypertension*, 2023; 41(1):187-193.

1 Introduction

Cardiovascular diseases are a major cause of death in Finland as well as globally (GBD 2017 Causes of Death Collaborators, 2018; Roth et al., 2020; Statistics Finland, 2022; N. Townsend et al., 2022). Large arterial stiffening is a key factor behind the development of hypertension (Dumor et al., 2018; Kaess et al., 2012) and increased blood pressure (BP) commonly underlies cardiovascular diseases (Roth et al., 2020). High night-time ambulatory BP (ABP) and reduced nocturnal decline in BP (i.e., nocturnal BP dipping, hereafter BP dipping) in particular have been found to predict cardiovascular events and mortality (Hermida et al., 2011, 2020; Salles et al., 2016; Yang et al., 2019). From a clinical point of view, a 5-mmHg increase in home diastolic BP (DBP) and a 10-mmHg increase in home systolic BP (SBP) significantly increase the risk of cardiovascular events, cardiovascular mortality and all-cause mortality (Ward et al., 2012). In addition, a 5-mmHg elevation in home DBP and a 10-mmHg elevation of home SBP is related to a 18% and 29% higher risk of stroke (Ohkubo et al., 2004).

Earlier systematic reviews and meta-analyses have found that work-related psychosocial stressors increase the risk of coronary disease and other cardiovascular diseases, especially among men (Backé et al., 2012; Eller et al., 2009; Kivimäki et al., 2006, 2012). However, according to one systematic review and meta-analysis, it remains unclear whether job strain is related to the 24-hour BP profile and the BP dipping among aging workers (Landsbergis et al., 2013).

Some studies have examined the association between work-related psychosocial and private life stressors, and large arterial stiffness (Bomhof-Roordink et al., 2015; Kaewboonchoo et al., 2018; Massamba et al., 2023; Michikawa et al., 2008; Nomura et al., 2005; Otsuka et al., 2009; Slepecky et al., 2017; Utsugi et al., 2009). However, the results of these studies are contradictory. The participants have mainly been young Asians and in several instances pulse wave velocity (PWV; i.e. a measure of large arterial stiffness) has been measured using nonstandard methods (augmentation index (AIx), brachial-ankle PWV and finger photoplethysmogram (Bomhof-Roordink et al., 2015; Kaewboonchoo et al., 2018; Nomura et al., 2005; Otsuka et al., 2009; Slepecky et al., 2017; Utsugi et al., 2009)).

An earlier study has established that home BP values are at their highest at the beginning of the week and their lowest on the weekend (Juhanoja et al., 2016). In addition, BP was usually higher on working days than on days off work (Del Arco-Galan et al., 1994; Enström & Pennert, 1996; Goldstein et al., 1992, 1999; Riese et al., 2004; Vrijkotte et al., 2000). However, only a few earlier studies have focused on the differences between BP on working days and days off in relation to work-related psychosocial stressors (Riese et al., 2004; Vrijkotte et al., 2000). These studies have provided conflicting findings.

As a stressful period, the retirement transition has also been associated with changes in cardiovascular risk factors. Body mass index (BMI) has been found to decrease especially among men who retire from sedentary work, and to increase especially among women who retire from diverse or physically strenuous jobs (Stenholm et al., 2017). Sedentary time increases among women and retirees with manual occupations before retirement in particular (Suorsa et al., 2021). Physical activity increases among men retiring from nonmanual occupations and decreases among women retiring from manual occupations (Pulakka et al., 2020). Sleep duration (Myllyntausta et al., 2017) and smoking cessation increases (Pulakka et al., 2019), and alcohol consumption either remains stable, temporarily increases or slowly declines during the retirement transition (Halonen et al., 2017). A few studies have examined the association between retirement and BP, resulting in conflicting findings (Ekerdt et al., 1984; Q. Wang, 2020; Xue et al., 2017). Because the majority of these studies have been performed on young Chinese participants and have used only office BP, studies using out-of-office BP measurements that are currently recommended for diagnosing hypertension, are also needed.

Thus, this study aimed to address the gaps in the current literature by examining, (i) how work-related factors are associated with ABP profiles and BP dipping among aging workers, (ii) how life stressors and their accumulation are related to large arterial stiffness among aging workers, (iii) how work-related psychosocial stressors are associated with home BP on weekdays and weekends, and (iv) how the ABP profile changes during the retirement transition.

2 Review of the Literature

2.1 Atherosclerosis and cardiovascular health

The arteries consist of the intima, the inner part of which is the endothelium, and the outer part of which contains collagen and elastic fibers (Jebari-Benslaiman et al., 2022). The middle layer of the arteries consists of smooth muscle and elastic and collagenous tissue and is called the media (Jebari-Benslaiman et al., 2022). The outermost layer of the arteries is called the adventitia, and it joins them to other body tissues and contains connective tissue and vascular nerves (Jebari-Benslaiman et al., 2022).

The inflammatory process of lipid accumulating in the intima layer is the first step in the development of atherosclerotic disease (e.g. heart attack, stroke, peripheral arterial disease (Mustajoki, 2020)). A turbulent blood flow causes endothelial dysfunction, helping low-density lipoprotein (LDL) cholesterol particles infiltrate the intima (Jebari-Benslaiman et al., 2022). Aging and other cardiovascular disease risk factors, such as diet rich in fats and tobacco smoke, further promote endothelial dysfunction (Favarato & Lemos da Luz, 2018). As a result, atheroma plaque begins to form (Jebari-Benslaiman et al., 2022). In the next stages, the monocytes enter the intima, and together with the smooth muscle cells, they capture the LDL cholesterol particles, forming foam cells. As a result of the activation of several inflammatory signaling pathways, the LDL particles gather not only inside the cells, but also within the extracellular space, contributing to the formation of a fatty streak (Jebari-Benslaiman et al., 2022). Oxidative stress furtherly promotes endothelial dysfunction **(Figure 1)**. As the process of atherosclerosis advances, fibrous plaque begins to form. This has a necrotic core, which in turn consists of lipids, but not cells. The fibrous cap, that is, the layer of fibers around the necrotic core, is another indication of advanced atherosclerosis (Jebari-Benslaiman et al., 2022).

Finally, the metabolism of the macrophages and the dying smooth muscle cells cause the atheroma plaque to calcify (Jebari-Benslaiman et al., 2022). As a result of the calcification process, microcalcifications form, which over time become larger calcifications, covering both the intima and the media layers of the artery and extending from the necrotic core to the surrounding material (Jebari-Benslaiman et al., 2022).

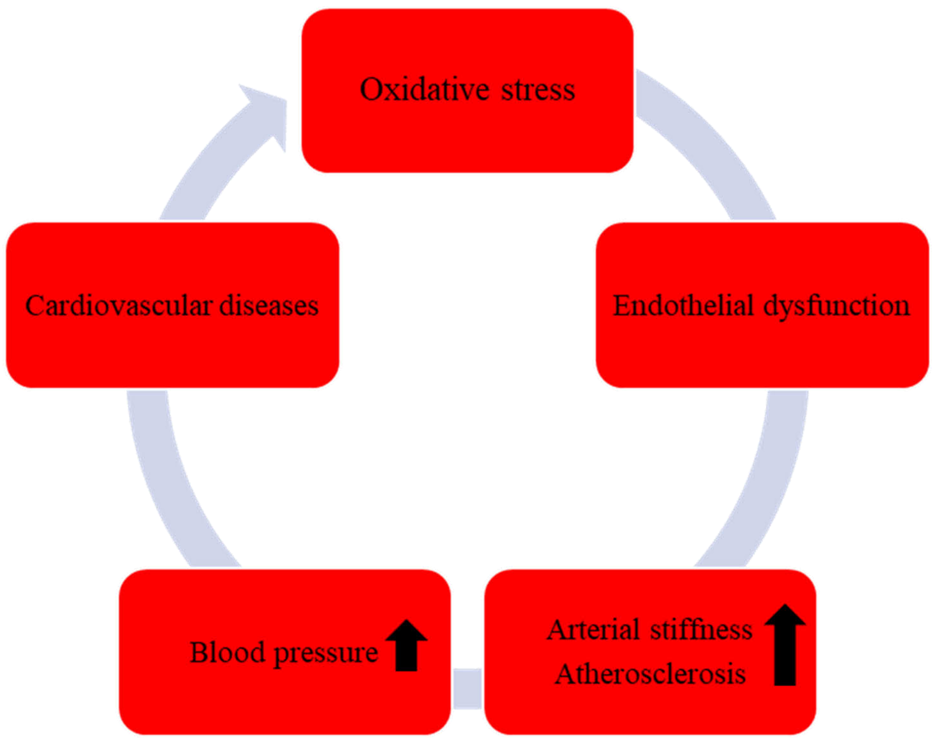

Figure 1. Development of cardiovascular diseases (Favarato & Lemos da Luz, 2018; Jebari-Benslaiman et al., 2022; Mikael et al., 2017).

The thickness of the fibrous cap and the inflammatory agents largely determine how susceptible the plaque is to rupture (Jebari-Benslaiman et al., 2022). Clinical manifestations occur when the artery narrows due to the atheroma plaque or when the plaque ruptures. A rupture is caused by tensile stress or a thin fibrous cap; a coagulation process is activated and the platelets cover the wound. A coagulation cascade then forms thrombin and fibrin (Jebari-Benslaiman et al., 2022). The wound becomes covered by thrombus, formed by the fibrin and platelets. The thrombus narrows the arterial lumen, leaving less space for the blood flow (Jebari-Benslaiman et al., 2022). If the arterial lumen is not completely obstructed, cardiovascular system symptoms may remain, at the level of, for example, angina pectoris. However, if the thrombus completely obstructs the arterial lumen, the result is more severe, and for instance a myocardial infarction may occur (Jebari-Benslaiman et al., 2022).

The mechanisms how stress results in clinical outcomes are presented in **Figure 2**. Globally, atherosclerosis is one of the leading causes of death, as ischemic heart disease, ischemic stroke and, to a lesser extent, peripheral vascular disease, are the major causes of death among not only cardiovascular diseases but also among noncommunicable diseases (GBD 2015 Mortality and Causes of Death Collaborators, 2016; Vaduganathan et al., 2022). Cardiovascular diseases are also a common cause of disability worldwide (Vaduganathan et al., 2022). Similarly, in Europe, cardiovascular diseases account for the majority of deaths and of the cardiovascular diseases, ischemic heart disease is the leading cause of death (N. Townsend et al., 2022). In Finland, cardiovascular diseases account for 37% of all deaths (N. Townsend et al., 2022). The age-standardized mortality from cardiovascular diseases is 250–350 for women and 350–450 for men per 100 000 in Finland, and the age-standardized incidence of cardiovascular diseases is 1287 for women and 1711 for men per 100 000 in Finland (N. Townsend et al., 2022).

Following changes happen when the people age: endothelial dysfunction and artery stiffening (Donato et al., 2018). Similar to atherosclerosis, endothelial dysfunction often precedes arterial hypertension (Favarato & Lemos da Luz, 2018). Large arterial stiffness is mainly caused by a loss of elasticity, increased wall diameter and blood vessel calcification (Mikael et al., 2017). When the heart contracts during the systole, the arteries undergo a pulse wave. The stiffer the arteries, the earlier the pulse wave is reflected back from the peripheral arteries. If the reflected wave arrives at the heart during the systole, both pulse pressure and SBP increase, resulting in left ventricular hypertrophy due to additional pressure load (Laurent et al., 2006; Safar, 2017; Safar et al., 2003). The reflected waves are thought to increase the SBP already after turning 30 years old (O’Rourke & Hashimoto, 2007). Increased large arterial stiffness often precedes hypertension (Dumor et al., 2018; Safar, 2017; Safar et al., 2003) and has shown to predict cardiovascular events even when other conventional risk factors have been adjusted for (Mitchell et al., 2010).

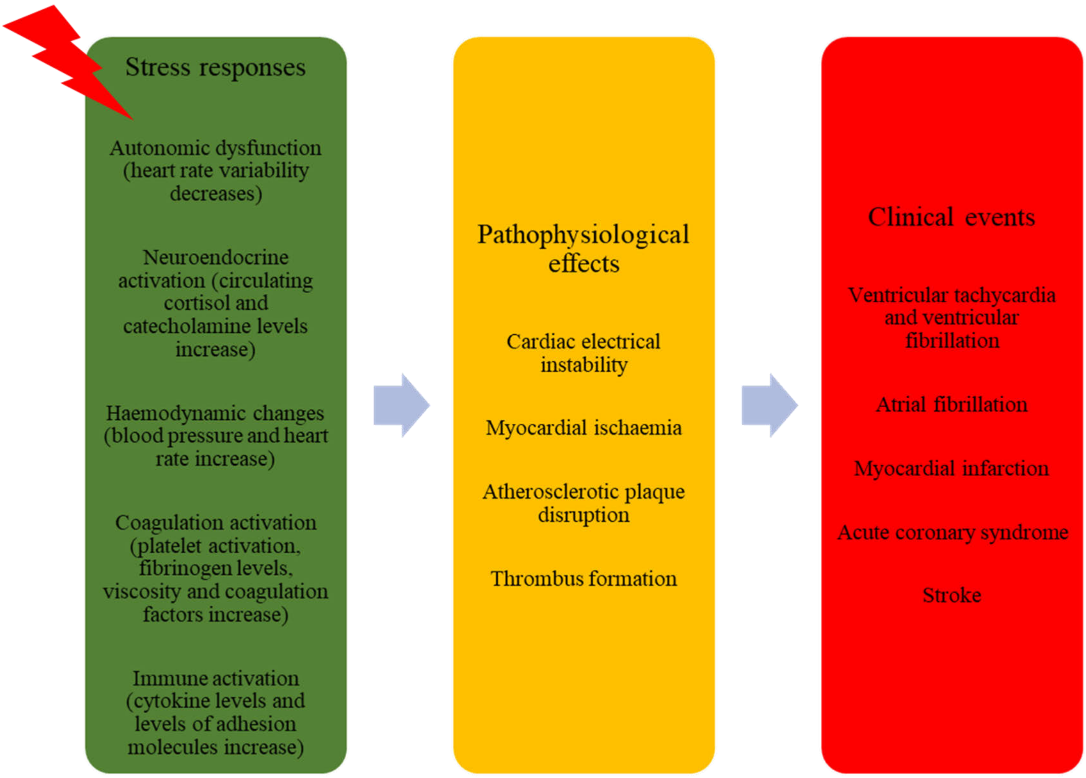

Figure 2. Stress effects on cardiovascular health modified from Kivimäki & Steptoe.

2.2 Markers of cardiovascular health

2.2.1 Office, home and ambulatory blood pressure

Office BP is a widely used and studied method for measuring BP (Stergiou et al., 2021). It is usually measured by an automatic device or a manual auscultatory device (Stergiou et al., 2021). However, office BP does not detect the white coat effect (a phenomenon in which BP is higher at the office than at home). A hypertension diagnosis should be based on home BP or ABP (Stergiou et al., 2021), as both predict cardiovascular risk better than office BP (Niiranen et al., 2010; Yang et al., 2019).

BP is often measured at home using an electronic upper-arm cuff device (Parati et al., 2010; Stergiou et al., 2021). *Home BP* is superior to office BP for diagnosing hypertension and for assessing the effectiveness of antihypertensive drug treatment (Stergiou & Bliziotis, 2011). Measuring BP at home enables avoiding the white coat effect (elevated office BP but normal out-of-office BP) and can detect masked hypertension (elevated out-of-office BP but normal office BP) (Stergiou et al., 2021). Furthermore, it also enables the detection of the consequences of excessive medication for hypertension in cases of white coat hypertension (Stergiou & Bliziotis, 2011). In addition, home BP enables several BP measurements of the same individual (Stergiou et al., 2021). However, the disadvantage of home BP is that as it is performed by the individuals themselves, incorrect use of the BP device and errors in reporting the BP values, for instance, may cause inaccuracies (Stergiou et al., 2021).

ABP is measured using an electronic upper-arm cuff device that provides BP surveillance over 24 hours and during common daily activities (Stergiou et al., 2021). White coat hypertension and masked hypertension can be diagnosed by means of ABP if the office BP is also known (Stergiou et al., 2021). As the participants write down their daily activities, bedtimes, awakening times, and possible symptoms, the ABP profile provides information that could not be achieved using other BP measurement methods. According to two meta-analyses (Hansen et al., 2007; Kollias et al., 2024), daytime ABP and home BP predict cardiovascular events and mortality better than BP measurements taken at the office. Furthermore, knowledge of the participants' night-time BP and BP dipping (calculated as [1−(asleepBP/awakeBP)]×100), enables even more accurate assessments of BP-related cardiovascular risk (Dolan et al., 2005; Fagard et al., 2008; Kikuya et al., 2005; Yang et al., 2019). However, ABP measurement may be rather unpleasant for patients and furthermore, it is not widely available and is expensive (Stergiou et al., 2021). **Table 1** presents the BP threshold values for elevated systolic and diastolic office BP, home BP and ABP of the European Society of Hypertension (ESH)

(Mancia et al., 2023) and **Table 2** presents the ESH's BP dipping threshold values (Mancia et al., 2023; Parati et al., 2014).

Table 1. Threshold values for office and out-of-office BP values (Stergiou et al., 2021).

BP measurement method	Threshold for hypertension
Office BP	≥140/90 mmHg
Home BP	≥135/85 mmHg
ABP	24-hour average: ≥130/80 mmHg Daytime (awake) average: ≥135/85 mmHg Night-time (asleep) average: ≥120/70 mmHg

BP Blood pressure, *ABP* Ambulatory blood pressure

Table 2. BP dipping categories based on awake and asleep BP values (Parati et al., 2014).

Category	BP dipping
Extreme dipping	>20%
Dipping	≥10% and ≤20%
Nondipping	<10%
Reverse dipping	<0%

BP Blood pressure

2.2.2 Large arterial stiffness

Large arterial stiffness is usually related to changes in the mechanical properties of the arterial wall (Avolio, 2013). The processes underlying increased large arterial stiffness are partly similar to those that cause atherosclerosis: endothelial dysfunction, reduced nitric oxide availability, chronic inflammation and changes in elastin and collagen fibers (Palombo & Kozakova, 2016). Moreover, large arterial stiffness and atherosclerosis have common determinants, as both are associated with increasing age and risk factors related to metabolism, for instance (Palombo & Kozakova, 2016).

As large arterial stiffness increases, arterial pulse waves advance more rapidly in the arterial tree, eventually reaching the periphery and reflecting backward earlier than normal (Palombo & Kozakova, 2016). As a consequence, the backward waves arrive at the ascending aorta during the systolic phase instead of the diastolic phase, increasing the aortic systolic pressure and pulse pressure, diminishing diastolic coronary perfusion pressure, and finally reducing myocardial oxygen delivery (Laurent et al., 2006; Palombo & Kozakova, 2016). In addition, the augmenting aortic systolic pressure increases the left ventricular afterload and consequently the myocardial workload, resulting in the left ventricular hypertrophy and an increased oxygen demand (Laurent et al., 2006; Palombo & Kozakova, 2016). As the supply for oxygen decreases while demand increases, the myocardium is more susceptible to ischemia.

The carotid-femoral PWV has been considered the gold standard for measuring large arterial stiffness (Laurent et al., 2006; Palombo & Kozakova, 2016). Measuring carotid-femoral PWV reveals the stiffness of the arteries located nearest to the left ventricle, and thus provides information on the actual effects of increased large arterial stiffness (Laurent et al., 2006). Several studies have found that increased carotid-femoral PWV is associated with an increased risk of cardiovascular events and mortality (Ben-Shlomo et al., 2014; Laurent et al., 2001; Mitchell et al., 2010; Palombo & Kozakova, 2016; Zhong et al., 2018). However, aortic stiffness is sometimes evaluated by central pulse wave analysis and the impact of large arterial stiffness is sometimes assessed by wave reflections measured by the AIx or finger photoplethysmography (Laurent et al., 2006). In some studies, the brachial-ankle PWV is also used to assess large arterial stiffness (Laurent et al., 2006). PWV normally increases from 4–5 m/s in the ascending aorta, to 5–6 m/s in the abdominal aorta, and to 8–9 m/s in the iliac and femoral arteries, indicating that the proximal arteries tend to be more elastic and the peripheral muscular arteries to be stiffer (Laurent et al., 2006). However, as regards the prediction of cardiovascular events, a threshold value of 10 m/s for carotid-femoral PWV has been considered suitable, but this depends on the methods and standardization (Van Bortel et al., 2012).

2.3 Determinants of cardiovascular health

The protective and risk factors for atherosclerosis and the onset of cardiovascular disease (GBD 2015 Risk Factors Collaborators, 2016; Roth et al., 2020), including sociodemographic factors, lifestyle factors, biological risk factors, and environmental factors, are on a wide spectrum.

The strongest sociodemographic determinant of cardiovascular health is age. Cardiovascular morbidity and mortality increase with age (Sinclair & North, 2012) as atherosclerosis advances (Head et al., 2017; J. C. Wang & Bennett, 2012). Sex is also an important determinant of cardiovascular disease risk, as men are at a higher risk of cardiovascular diseases, and women’s risk of cardiovascular diseases increases in older age (Mikkola et al., 2013; Woodward, 2019). Women also exhibit partly different risk factors for cardiovascular diseases than men (Rajendran et al., 2023). Socioeconomic status has been found to affect the risk of cardiovascular diseases, as individuals with lower incomes and education, those who are unemployed and those who live in disadvantaged neighborhoods are more susceptible to cardiovascular diseases and cardiovascular mortality than their counterparts (Schultz et al., 2018).

Smoking is one of the main modifiable risk factors for atherosclerosis and cardiovascular diseases (Klein, 2022). Current smoking in particular is associated with a higher risk of atherosclerosis than that of nonsmokers, and quitting smoking may decrease the risk of atherosclerosis (Bermúdez-López et al., 2023; Cheezum et al., 2017; Nakanishi et al., 2015). In a meta-analysis and a multicenter study, current smokers manifested a higher risk of cardiovascular events and cardiovascular mortality than individuals who had quit smoking or had never smoked (Mons et al., 2015; Nakanishi et al., 2015). According to another meta-analysis, even light smoking can increase the risk of coronary heart disease and stroke (Hackshaw et al., 2018).

Moderate alcohol intake has been associated with a decreased risk of atherosclerosis (Chevli et al., 2020; Laguzzi et al., 2021; D. Wang et al., 2019), while higher alcohol consumption has been linked to an increased risk of atherosclerosis (Chevli et al., 2020; Zhou et al., 2023). However, the results of these studies seem to vary according to the atherosclerosis' measurement methods used and the participants' sex, for example. Alcohol consumption has been linked to both a decreased and an increased risk of cardiovascular disease and cardiovascular disease mortality, depending on the amount of alcohol consumed and when it is consumed, for instance (Hange et al., 2015; Mostofsky et al., 2016; Smyth et al., 2015).

Another determinant of atherosclerosis is diet. The Ketogenic diet, the Dietary Approaches to Stop Hypertension diet, the Mediterranean diet, functional products and dietary supplements with anti-atherosclerotic effects have been found to prevent the development of atherosclerosis whereas diets with a high content of refined carbohydrates or sugar, trans fatty acids and saturated fats, excess sodium, and a deficiency of vitamins or dietary fiber have shown to be risk factors for atherosclerosis (Vesnina et al., 2022). A recent meta-analysis confirmed that trans fatty acids, although not other types of fatty acids, increase the risk of cardiovascular diseases whereas polyunsaturated fatty acids showed an even beneficial effect on cardiac health (Zhu et al., 2019). Meta-analyses have discovered that high salt consumption is also associated with an increased risk of cardiovascular diseases (Y. J. Wang et al., 2020) and cardiovascular mortality (Poggio et al., 2015). In addition, red meat has been linked to an increased risk of cardiovascular disease and cardiovascular mortality (Al-Shaar et al., 2020; Zheng et al., 2019). Furthermore, a recent meta-analysis found that many carbohydrate foods either reduce or maintain the risk of cardiovascular diseases (Kwok et al., 2019). Fruits and vegetables mainly maintain the risk, but fish products seem to reduce it (Kwok et al., 2019).

A systematic review by Palmefors et al. found that physical exercixe was related to favorable changes that prevent atherosclerosis development in patients at risk of or with established cardiovascular diseases. Physical activity has also been linked to a reduced risk of cardiovascular diseases in a meta-analysis by Li & Siegrist.

Classic modifiable cardiovascular disease risk factors are naturally important for cardiovascular health. A high blood glucose level is linked to both the onset and progression of atherosclerosis (Poznyak et al., 2020). The possible pathways between these two disease entities include chronic inflammation, oxidative stress, and genetic and epigenetic modifications. Moreover, type 1 and type 2 diabetics are at a higher, although declining risk of cardiovascular diseases and mortality, than nondiabetics (Damaskos et al., 2020; Htay et al., 2019; Rawshani et al., 2017). According to a certain guideline and one meta-analysis, high LDL cholesterol and triglyceride levels increase the risk of cardiovascular diseases (Arnett et al., 2019; Boekholdt et al., 2014), as do low levels of high-density lipoprotein cholesterol (Grundy et al., 2019). In addition, high SBP is a known risk factor for cardiovascular morbidity and mortality (Abbafati et al., 2020). A systematic review by Romero-Corral et al. found that, as obesity is associated with the development of atherosclerosis (Powell-Wiley et al., 2021) and high BMI is associated with an increased risk of cardiovascular morbidity and mortality (Abbafati et al., 2020), the association between high BMI and cardiovascular mortality in coronary artery disease patients is controversial. Eventually, the risk of individuals with impaired kidney function developing cardiovascular diseases increases, not only as a result of traditional risk factors, but also as a result of the mechanisms that are characteristic of kidney dysfunction (Jankowski et al., 2021).

Air pollution has been recently linked to the development of atherosclerosis (Bevan, Al-Kindi, Brook, & Rajagopalan, 2021; Bevan, Al-Kindi, Brook, Münzel, et al., 2021; Zhang et al., 2023), and in the past, has been found to increase the risk of cardiovascular events. One meta-analysis claimed that short-term exposure to particulate matter pollutants, carbon monoxide, nitrogen dioxide, sulfur dioxide (but not ozone) significantly increased the risk of myocardial infarction (Mustafić et al., 2012). However, another meta-analysis found that longer exposure (average follow-up period of 11.5 years) to certain particulate matters led to an increased risk of an acute coronary event although such an association was not found for other particulate matters, nitrogen oxide, soot, high traffic intensity on the nearest road, or the traffic load on major roads in a 100 m buffer (Cesaroni et al., 2014).

2.4 Life stressors as determinants of cardiovascular health

Work life consists of both physical and psychosocial stressors. This thesis, however, focuses on work-related psychosocial stressors. These include low job control, high job demands, lack of support at work, job insecurity, low rewards, and organizational injustice. One multicohort study and one meta-analysis have linked work-related stressors such us job strain and effort-reward imbalance (ERI) to an increased susceptibility to coronary heart disease (Dragano et al., 2017; Kivimäki et al., 2012), and a meta-analysis by Fransson et al. found that job strain was associated with ischemic, although not hemorrhagic, stroke.

2.4.1 Work-related factors and cardiovascular health

The *Job Content Questionnaire (JCQ)* is a widely used method for assessing job strain (Karasek et al., 1998). The first steps in creating the JCQ were taken in 1960s and in its early stages, it was based on the questions of three Quality of Employment Surveys collected by the University of Michigan Survey Research Center (Karasek et al., 1998). The first recommended version of the JCQ was published in 1985, and this was updated and published in 1995 (Karasek et al., 1998). The current version consists of 49 questions on the determinants of job control, job demands, social support, physical demands and job insecurity (Karasek et al., 1998). However, job strain is evaluated on the basis of only two categories: job control (nine questions) and job demands (five questions). Nevertheless, abbreviated versions of the questionnaire seem to correspond to more complete scales (Fransson et al., 2012), the response options being on a Likert scale (Fransson et al., 2012; Karasek et al., 1998). Accordingly, respondents are considered to have high job strain if they score low in job control and high in job demands on the JCQ (e.g. assemblers, freight handlers, waiters). Respectively, respondents scoring high in job control and high in job demands are categorized into the active job group (e.g., public officials, physicians, engineers, nurses), those scoring low in job control and low in job demands into the passive job group (e.g., billing clerks and janitors), and finally, respondents scoring high in job control and low in job demands are categorized into the low job strain group (e.g., reparation workers, line workers, natural scientists) (Karasek et al., 1998).

The *ERI* model is another way to assess the effects of work on individuals (Siegrist, 1996). It measures the imbalance between extrinsic (e.g., demands and obligations) and intrinsic (e.g., personal coping style) efforts, and rewards (money, esteem, status control) at work (Siegrist, 1996). The ERI model also considers how individuals perceive the imbalance by addressing overcommitment (a significant work-related commitment and a high need for approval) (Siegrist et al., 2004). The shortened version of the ERI model has been found to correspond to the original questionnaire (Siegrist et al., 2009, 2014).

The *Copenhagen Psychosocial Questionnaire (COPSOQ)* consists of 30 questions on the workplace; the work–individual interface; and the individual's health, well-being and personality (Kristensen et al., 2005). Mc Carthy et al. used questions on possibility for development and influence at work to assess job control.

In addition to JCQ, ERI and COPSOQ, there are numerous ways to measure work-related psychosocial stressors, but this thesis used the JCQ, as it is widely used method for measuring job strain in epidemiological studies (Fransson et al., 2012). **Table 3** presents previous studies of the association between job strain and ABP. Ten of the 14 studies (Clays et al., 2007, 2011; Fan et al., 2013; Fauvel et al., 2001; Landsbergis et al., 1994, 2003a; Schnall et al., 1992, 1998; Tobe et al., 2005, 2007) reported job strain-related increases in ABP. Moreover, SBP seemed to be more susceptible to increase from job strain than DBP. However, three studies found no association between job strain and ABP (Cesana et al., 1996; Fauvel et al., 2003; Maina et al., 2011). One study found that socioeconomic status could modify the relation between job strain and ABP as the participants with lower education (for DBP) or lower personal income (for SBP) manifested more unfavorable effect of job strain on ABP than their counterparts (Landsbergis et al., 2003b). Another study (Clays et al., 2011) found that high education level but not occupational status was significantly associated with reduced nondipping.

Three studies (Brown et al., 2006; Fan et al., 2013; Mc Carthy et al., 2014) have investigated the relation between work-related psychosocial stressors and ABP using the components of job strain. Low job control was related to higher asleep SBP and lower SBP dipping than high job control among men but not among women, but job demands were not related to ABP (Fan et al., 2013). In another study, psychosocial demands or decision latitude were not related to differences in ABP, but occupational status seemed to partially modulate ABP values (Brown et al., 2006). In one study (Mc Carthy et al., 2014) high possibility for development and high influence at work were partly related to higher ABP values and BP dipping.

Table 3. Studies of relation between job strain, job control, job demands, and ABP.

Author, year	**Study population**	**N (women, %)**	**Age (mean±SD or range, years)**	**Main findings[a]**
Job strain				
Schnall et al. (1992)	Workers from 8 worksites, United States	264 (0)	44.3±8.7	Job strain was significantly associated with increased SBP at work, at home and during sleep. Job strain was associated with increased DBP at work but not at home or during sleep.
Landsbergis et al. (1994)	Workers from 8 worksites, United States	262 (0)	44.3±8.6	Job strain was associated with significantly increased ABP (SBP, but not DBP).
Cesana et al. (1996)	Residents of city, Italy	527 (0)	25–64	No significant differences in ABP (SBP and DBP) were found in the job strain categories.
Schnall et al. (1998)	Workers from 8 worksites, United States	195 (0)	43.4±8.2	Job strain was associated with significantly higher ABP (except DBP during sleep).
Fauvel et al. (2001)	Workers from a chemical company, France	70 (unknown)	18–55	High strain was associated with significantly higher DBP and slightly higher SBP during working hours but not during leisure-time hours.
Landsbergis et al. (2003a)	Workers from 10 worksites, United States	213 (0)	30–60	Job strain was significantly associated with increased ABP.
Landsbergis et al. (2003b)	Workers from 8 worksites, United States	283 (0)	30–60	Education level (for DBP) and personal income (for SBP) significantly modified the association between job strain and ABP.
Fauvel et al. (2003)	Workers from a chemical company, France	132 (minority)	18–55	High strain was not associated with significantly increased ABP.
Tobe et al. (2005)	Full-time workers, Canada	248 (54)	50.8±6.6	Job strain was associated with increased SBP.

Tobe et al. (2007)	Workers, Canada	229 (54)	50.8±6.5	Job strain was associated with significantly increased SBP (but not DBP) during one year follow-up.
Clays et al. (2007)	Workers from 4 companies or public administrations, Belgium	178 (39)	40–64	Job strain was significantly associated with increased ABP (except DBP at home).
Maina et al. (2011)	Frontline call-handlers from two call centers, Italy	100 (74)	Women: 34.9±9.9, Men: 36.0±10.8	No significant association between job strain and ABP.
Clays et al. (2011)	Workers from 4 companies or public administrations, Belgium	167 (40)	40–64	Job strain was significantly associated with increased SBP and DBP nondipping. High education level but not occupational status was significantly associated with reduced nondipping.
Fan et al. (2013)	Workers, United States	122 (41)	30–60	Men: High strain significantly increased asleep SBP but not awake SBP and participants with high job strain had significantly smaller SBP dipping. No differences in DBP. Women: No significant differences.
Job control and job demands				
Brown et al. (2006)	Public school teachers, nurses, nurse's aides, United States	208 (100)	Nurses: 35.4±6.6, teachers: 46.3±7.5	Nurses had significantly higher SBP and DBP at work, at home but not during sleep. Neither psychological demands nor decision latitude (dimension of job control) were associated with ABP. Nurses scored significantly lower on decision latitude, but no differently on psychological demand.
Fan et al. (2013)	Workers, United States	122 (41)	30–60	Men: the low job control group had significantly higher asleep SBP and lower SBP dipping than the high job control group (but no difference during awake period or DBP). Women: no differences between job control groups.

				No significant difference between job demands groups' awake SBP/DBP, asleep SBP/DBP or SBP/DBP dipping.
Mc Carthy et al. (2014)	Patients from large primary health care center, Ireland	552 (unknown)	50–69	High possibility for development: significantly higher awake SBP, DBP and SBP dipping, no difference in asleep BP. High influence at work: significantly higher awake SBP, no difference in awake DBP, asleep BP or SBP dipping. Normotensive workers: High influence at work was associated with higher awake and asleep SBP and DBP but not SBP dipping. High possibility for development at work was only associated with higher asleep SBP.

[a]Assessment of stressor was JCQ in other studies but the COPSOQ was used by Mc Carthy et al.

ABP Ambulatory blood pressure, *SD* Standard deviation, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *BP* Blood pressure, *JCQ* Job content questionnaire, *COPSOQ* Copenhagen Psychosocial Questionnaire

Table 4 presents studies of the differences in ABP profiles in terms of worktime mode, i.e., different types of work shifts. Four of these studies examined the within-individual ABP profiles of day, evening and night shifts. Three studies found that evening and night shifts were unfavorable for the ABP profile (Fialho et al., 2006; Kitamura et al., 2002; Lo et al., 2008) whereas one study found night shifts to be more beneficial for the ABP profile than day shifts (Munakata et al., 2001). Two studies compared day-shift workers to evening- and night-shift workers and found that evening and night shifts were more associated with harmful changes in ABP than day shifts (Ohira et al., 2000; Yamasaki et al., 1998).

Table 4. Studies of relation between worktime mode and ABP.

Author, year	**Study population**	**N (women, %)**	**Age (mean±SD or range, years)**	**Main findings**
Yamasaki et al. (1998)	Nursing staff from a hospital, United States	93 (100)	30–59	Evening- and night-shift workers were significantly more often nondippers and had significantly higher asleep SBP than day-shift workers. No significant differences were found between the DBP and awake SBP of the evening- and night-shift workers, and those of the day-shift workers.
Ohira et al. (2000)	Workers from a nuclear power plant, Japan	53 (0)	20–45	Shift workers had significantly higher awake SBP during working hours (but not during leisure time or when sleeping) than day workers. No significant difference was found between shift and regular day workers' DBP in the unadjusted model. 24-hour unadjusted SBP (but not DBP) was higher among the shift workers. Shift workers had higher adjusted SBP during awake working hours and leisure time but not during 24-hour or during sleep.
Munakata et al. (2001)	Nurses from a hospital, Japan.	18 (100)	29±2	SBP and DBP were lower during the night shift and during the awake period after the night shift compared to the day shift (no difference in DBP during the shift). No differences were found during sleep after the shifts.
Kitamura et al. (2002)	Employees from a factory, Japan	12 (0)	53.6±2.5	Nondipping pattern more common during first night shift than during last day shift but this reversed to the dipping pattern on a few days when working night shifts.
Fialho et al. (2006)	Medical residents, Brazil	56 (46)	25.4±1.43	ABP and asleep DBP were significantly higher during 24-hour shift than during a normal working day (maximum 8 hours of work). No differences were found in awake SBP and DBP, asleep SBP or BP dipping status.
Lo et al. (2008)	Nurses from a hospital, Taiwan.	22 (100)	26–33	SBP and DBP increased significantly during sleep after a night or evening shift. BP did not completely return to baseline after night shift ($p < 0.05$). Shift work affected BP dipping.

ABP Ambulatory blood pressure, *SD* Standard deviation, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *BP* Blood pressure

Table 5a presents studies of the association between work-related psychosocial stressors and large arterial stiffness. These studies investigated the association between job strain, job demands or job control, and large arterial stiffness. The studies that used an AIx to evaluate large arterial stiffness found that job strain was significantly associated with an increased central AIx (Bomhof-Roordink et al., 2015), and significantly so among men (Otsuka et al., 2009). One study assessed large and peripheral arterial stiffness using pulse wave analysis based on a finger photoplethysmogram. It found that high job strain and high job demands, but not low job control, were significantly associated with increased large and peripheral arterial stiffness among men, but they found no associations among women (Kaewboonchoo et al., 2018). When men's large arterial stiffness was evaluated using aortic PWV, those with high job demands showed significantly higher large arterial stiffness than those with low job demands (Michikawa et al., 2008). No significant difference in large arterial stiffness was found according to job control or job strain status (Michikawa et al., 2008). Two studies assessed large arterial stiffness by brachial-ankle PWV and found that job strain was significantly associated with increased large arterial stiffness among women but not among men (Utsugi et al., 2009), and that job demands and job strain were significantly inversely associated with PWV, but that job control was significantly positively associated with PWV (Nomura et al., 2005). Only one study (Massamba et al., 2023) used carotid-femoral PWV to assess large arterial stiffness and found that neither job strain nor ERI at baseline was associated with overall large arterial stiffness after a 16.8-year follow-up. However, when the participants were studied according to their BP values, high baseline DBP in the high job strain group was associated with a higher large arterial stiffness after follow-up than that in the low job strain group, but low baseline DBP in the high job strain group was associated with less large arterial stiffness after follow-up than that in the low job strain group. An ERI and high SBP at baseline was associated with less large arterial stiffness after follow-up than having no ERI (Massamba et al., 2023).

2.4.2 Private life stressors and cardiovascular health

In addition to work life, individuals' private lives have many other stressors. Earlier reviews have found that certain private life stressors, for example caregiving (Ahn et al., 2022) and the death of a spouse (Buckley et al., 2010) pose an increased risk of cardiovascular disease. **Table 5b** presents studies that have examined the relation between private life stressors and large arterial stiffness. Other life stressors, such as childhood trauma, recent negative life events and daily difficulties were significantly related to increased large arterial stiffness evaluated by a central AIx, whereas negative life events during childhood were not associated with large arterial stiffness (Bomhof-Roordink et al., 2015). One study used the Social Readjustment Rating Scale to elicit life events and found that they were inversely associated with the AIx among hypertensive participants in an unadjusted model but found no other associations between life events and the AIx or aortic PWV (Slepecky et al., 2017).

Table 5a. Studies of relation between work-related psychosocial stressors and large arterial stiffness.

Author, year	**Study population**	**N (women, %)**	**Age (mean±SD or range, years)**	**Main findings**
Nomura et al. (2005)	Company workers, Japan	396 (0)	26–34	Large arterial stiffness (measured by brachial-ankle PWV) was significantly inversely associated with job strain and job demands and positively associated with job control in uni- and multivariate analyses (but not job demands in univariate analysis).
Michikawa et al. (2008)	Factory workers, Japan	352 (0)	41.7±9.1	Participants with high job demands had significantly higher PWV of the aorta than participants with low job demands. No significant difference in job control or job strain.
Utsugi et al. (2009)	Local government employees, Japan	4266 (20)	Men: 48.3±6.8, women: 46.7±7.2	Job strain was significantly associated with increased large arterial stiffness (measured by brachial-ankle PWV) among women but not among men.
Otsuka et al. (2009)	Company workers, Japan	808 (0)	47±5	High job strain was associated with a significantly increased radial arterial wave reflection (expressed by AIx).
Bomhof-Roordink et al. (2015)	Participants with and without depressive or/and anxiety disorder, The Netherlands	618 (unknown)	46.5±12.1	Job strain was significantly associated with increased central arterial wave reflection (measured by central AIx).
Kaewboonchoo et al. (2018)	Enterprise employees, Thailand	2141 (60)	Men: 34.346±7.945, women: 34.885±8.492	High job demands were significantly associated with higher large and peripheral arterial stiffness (evaluated by pulse wave analysis based on a finger photoplethysmogram) among men. No difference in job control among men, or in job demands or job control among women. Among men, high job strain was significantly associated with higher large and peripheral arterial

				stiffness, but no difference was found in the other strain groups or among women.
Massamba et al. (2023)	White-collar workers from 19 public organizations, Canada	1736 (52)	Age at baseline: 44.9±6.7	Job strain status or effort–reward imbalance status was not associated with large arterial stiffness measured by carotid-femoral PWV during a follow-up of 16.8 years. Blood pressure modified the PWV differences between the different job strain groups and effort–reward imbalance groups.

SD Standard deviation, *PWV* Pulse wave velocity, *AIx* Augmentation Index

Table 5b. Studies of relation between private life stressors and large arterial stiffness.

Author, year	Study population	N (women, %)	Age (mean±SD or range, years)	Main findings
Bomhof-Roordink et al. (2015)	Participants with and without depressive or/and anxiety disorder, The Netherlands	618 (unknown)	46.5±12.1	Childhood trauma, recent negative life events and daily difficulties were significantly associated with increased central arterial stiffness (evaluated by central AIx). Negative life events during childhood were not associated with large arterial stiffness.
Slepecky et al. (2017)	Healthy participants and arterial hypertension patients, Slovakia	99 (64)	40.5±14.0	SRRS correlated significantly inversely in an unadjusted model with AIx among participants with hypertension, otherwise no associations were found between SRRS and AIx and aortic PWV.

SD Standard deviation, *AIx* Augmentation Index, *SRRS* Social Readjustment Rating Scale, PWV Pulse wave velocity

2.4.3 Cardiovascular health during working week and retirement transition

Table 6 presents studies that have compared the ABP profile of working days and the ABP profile of days off. These studies have found that BP values were mainly higher during time at work than during time at home (Del Arco-Galan et al., 1994; Enström & Pennert, 1996; Goldstein et al., 1992, 1999; Vrijkotte et al., 2000). One study investigated home BP values over one week (**Table 6**) and found that participants' home BP was at its highest on Monday and at its lowest on weekend days (Juhanoja et al., 2016).

Two studies have examined the effects of work-related psychosocial stressors on ABP on days off (**Table 6**). One of them found that BP was higher on working days than on days off, but that work-related psychosocial stressors did not affect BP on days off (Riese et al., 2004). The other study found that a high effort-reward imbalance associated with higher SBP (but not DBP) on working days and days off, but that overcommitment had no association with BP (Vrijkotte et al., 2000). These two studies did not include night-time values.

One systematic review found a possible association between retirement transition and an increased risk of cardiovascular diseases (Xue et al., 2020). Three studies have investigated changes in office BP during the retirement transition (**Table 7**). Two other studies examining within-individual changes in BP after the retirement transition found an association with beneficial changes in office BP (Q. Wang, 2020; Xue et al., 2017). One study, which compared the BP of working men to the BP of retiring men found that the BP of those who were retired increased more than the BP of the workers, although the hypertension rate did not increase (Ekerdt et al., 1984).

Table 6. Studies of ABP during working hours and leisure time.

Author, year	Study population	N (women, %)	Age (mean±SD or range, years)	Main findings
Goldstein et al. (1992)	Paramedics, United States	30 (0)	20–43	No difference between 24-hour, awake or asleep SBP or DBP on workday and on days off. BP was higher during specific working day situations than on days off.
Del Arco-Galan et al. (1994)	Physicians, staff and residents working in an emergency room, Spain	100 (51)	24–46	Significantly higher 24-hour, awake and asleep SBP and DBP when on call than on days off, except for asleep SBP.
Enström & Pennert (1996)	Treated hypertensives and normotensives in many different types of jobs, Sweden	80 (50)	Normotensives: 51.4 (44–64), Hypertensives: 54.7 (41–64)	Normotensives: Significantly higher 24-hour and daytime SBP and DBP on working days than on days off. Hypertensives: significantly higher 24-hour and daytime DBP on working days than days off, no difference in SBP. During night-time, no differences between normotensives or hypertensives on working days and days off.
Goldstein et al. (1999)	Female nurses, United States	138 (100)	37.8±6.3	Daytime and evening: SBP and DBP were significantly higher on working days than on days off. DBP significantly higher during daytime than evening on working days.
Juhanoja et al. (2016)	Population-based sample, Finland	1852 (54)	56.4±8.5	SBP and DBP were lowest at the weekend and highest on Monday, especially among the employed.
Work-related psychosocial stressors considered				
Vrijkotte et al. (2000)	White-collar workers, The Netherlands	109 (0)	47.2±5.3	SBP was higher during working hours than during leisure time on a working day. SBP was higher on a working day than a day off. A high effort-reward imbalance was associated with significantly higher

				SBP (but not DBP) on working days and days off. Overcommitment or interaction of overcommitment with imbalance had no association with ABP.
Riese et al. (2004)	Nurses, The Netherlands	159 (100)	35.9±8.5	SBP and DBP were significantly higher on working days than on days off. Job strain had no effect on BP. High job demands caused higher SBP at work. High job demands and decision latitude caused highest DBP at work.

ABP Ambulatory blood pressure, *SD* Standard deviation, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure, *BP* Blood pressure

Table 7. Studies of changes in office BP during retirement transition.

Author, year	**Study population**	**N (women, %)**	**Age (mean±SD or range, years)**	**Research design and follow-up**	**Main findings**
Ekerdt et al. (1984)	Community-dwelling men, United States	542 (0)	55–74	SBP and DBP were examined among men who retired and men who remained working during the study. Time interval between two measurements: 2.5–5.5 years.	Retirees had a significantly higher increase in SDB and DBP than workers but the rate of hypertension had not increased during retirement transition among the normotensive men at first measurement.
Xue et al. (2017)	Population-based sample, China	1084 (41)	46.4±9.1	Association between retirement, SBP and DBP was assessed over a 17-year period, one measurement taken before and another after retirement demanded.	Increase in SBP significantly decelerated and DBP significantly decreased after retirement. More robust relationship among men and urban dwellers.
Q. Wang (2020)	Population-based sample, China	3614 (58)	59.17±6.49	The relationships between retirement, leisure-time physical activity and BP were examined. Mean length of time in retirement: 7.87 years.	SBP and DBP and hypertension rates significantly decreased as the retirement transition became more distant. Physical activity mediated these changes.

BP Blood Pressure, *SD* Standard deviation, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure

2.5 Gaps in the previous literature

The association between work-related psychosocial stressors and office BP and ABP has been widely reported (Gilbert-Ouimet et al., 2014; Landsbergis et al., 2013). However, most previous studies have focused on middle-aged or younger participants and not considered BP dipping. Although some studies have examined the relation between shiftwork and BP (Esquirol et al., 2011), the studies that focused on ABP often had young populations (under 40 years of age), a limited sample size of 12–93 participants, or their participants have represented a restricted number of occupations or professions. Moreover, little is known about the relationship between occupational status and ABP. Consequently, Study I examined the relation between work-related psychosocial stressors, worktime mode, occupational status, ABP and BP dipping among aging workers from a wide variety of occupations.

Several studies have examined the association between work-related psychosocial stressors and large arterial stiffness (Bomhof-Roordink et al., 2015; Kaewboonchoo et al., 2018; Massamba et al., 2023; Michikawa et al., 2008; Nomura et al., 2005; Otsuka et al., 2009; Utsugi et al., 2009). However, only one study (Massamba et al., 2023) has used the gold standard for measuring noninvasive large arterial stiffness, carotid-femoral PWV (R. R. Townsend et al., 2015), and the majority of studies have focused on Asian, rather than European population. Only two studies have previously examined the association between life stressors other than work-related psychosocial stressors and large arterial stiffness (Bomhof-Roordink et al., 2015; Slepecky et al., 2017). However, these studies did neither use the gold standard for measuring noninvasive large arterial stiffness—carotid-femoral velocity (R. R. Townsend et al., 2015). Although some research is available on the relationship between cumulative stressors and cardiovascular health and disease risk (Albert et al., 2013; Burroughs Peña et al., 2019), little is known about the relationship between cumulative life stressors and large arterial stiffness. Accordingly, Study II examined the relation between job strain, certain private life stressors and large arterial stiffness among retiring Finnish public sector workers. It also explored the relation between the sum of cumulative stressors and large arterial stiffness.

Most earlier studies examining ABP or home BP, have found that BP is higher at work or among participants with job strain than it is at home or among participants with no job strain (Clays et al., 2007; Del Arco-Galan et al., 1994; Enström & Pennert, 1996; Goldstein et al., 1992, 1999; Juhanoja et al., 2016; Riese et al., 2004; Schnall et al., 1998; Vrijkotte et al., 2000). The findings regarding the association between work-related psychosocial stressors and awake ABP levels during days off are conflicting (Riese et al., 2004; Vrijkotte et al., 2000). As one earlier study reported that home BP values were lower at the weekend and higher at the beginning of the week, especially among employed participants (Juhanoja et al., 2016), Study III examined whether work-related psychosocial stressors explained these differences in BP.

The above studies have associated retirement transition with mainly beneficial changes in office BP (Ekerdt et al., 1984; Q. Wang, 2020; Xue et al., 2017). However, there is a lack of studies examining Western workers undergoing the statutory retirement transition using repeated ABP measurements. Consequently, Study IV focused on this area, as ABP is a better predictor of cardiovascular outcomes and mortality than office BP (Yang et al., 2019).

3 Aims

The overall aim of this thesis was to examine how work-related factors and private-life stressors are associated with ABP and large arterial stiffness. It also studied the changes in BP during the working week and retirement transition.

The specific aims of this thesis were:

1) To examine how work-related factors are associated with the ABP profile and BP dipping of aging workers (I).
2) To study how work-related psychosocial and private-life stressors and their accumulation is related to large arterial stiffness among aging workers (II).
3) To determine how work-related psychosocial stressors are associated with home BP on weekdays and weekend days (III).
4) To investigate how the ABP profile changes during the retirement transition and whether demographic or work-related factors moderate these changes (IV).

4 Materials and Methods

4.1 Participants and study design

This thesis utilizes three cohort studies: the Finnish Retirement and Aging (FIREA) study (I, II, IV), the DIetary, Lifestyle, and Genetic determinants of Obesity and Metabolic syndrome (DILGOM) study (I) and the Health 2000 study (III).

4.1.1 The FIREA study

The FIREA study was launched in 2013 at the University of Turku and its aim was to study the changes in health behavioral and cardiometabolic risk factors during the retirement transition (Stenholm et al., 2023). The study population comprised public sector employees who worked in any town in Southwest Finland or in any of the preselected nine towns or five hospital districts in Finland in 2012, and whose estimated statutory retirement date was between 2014 and 2019 (n=10,629). The participants' estimated individual retirement date was obtained from the pension insurance institute for the municipal sector in Finland (Keva) (*About Keva*, 2024). The participants were invited to participate in the FIREA study by asking them to complete a questionnaire 18 months prior to their estimated retirement date. After this, they were sent questionnaires once a year with the aim to gather data from at least two timepoints before and two timepoints after the transition to statutory retirement. The actual date of retirement was elicited from the participants. In total, 6,783 participants had responded to at least one questionnaire by the end of 2018 (Stenholm et al., 2023).

The FIREA clinical substudy was launched in 2015 and Finnish-speaking survey cohort participants who were still working, who had an estimated statutory retirement date between 2017 and 2019 and who lived in Southwest Finland were invited to participate (n=773) (Stenholm et al., 2023). Of these, 290 consented to participate in an annual clinical examination at the University of Turku. Up to five annual follow-up visits were conducted, until the participants had retired.

The FIREA study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the Hospital District of Southwest

Finland (Stenholm et al., 2023). All the participants provided written informed consent to participate in the study.

Those who had an adequate number of valid ABP measurements (at least 20 awake measurements or at least seven asleep measurements (Parati et al., 2014)) and information on covariates were included (n=149) in Study I.

Those with available PWV measurements and information on life stressors were included (n=258) in Study II.

Those with at least one valid BP measurement before and after their retirement transition were included (n=114 for ABP measurements and n=250 for office BP measurements) in Study IV.

4.1.2 The DILGOM Study

The DILGOM study (Konttinen et al., 2017) was a substudy of the FINRISK 2007 study (Peltonen et al., 2008) which aimed to examine in more detail the association between nutrition, lifestyle, psychosocial risk factors, environment, inheritance, obesity, and the metabolic syndrome. DILGOM 2014 was a follow-up study of those who had participated in 2007 in both the FINRISK and DILGOM 2007 studies, who did not forbid the use of their information for study purposes, and were still alive at the end of 2013 (n=4582). The DILGOM 2014 study was conducted in the same five areas as the earlier DILGOM 2007 study, but the health examination was only performed on those living in the areas of Helsinki, Vantaa, Turku or Loimaa. The rest received a postal questionnaire. Participants living in the Turku or Loimaa areas were invited to take part in the cardiovascular substudy (n=453), and 290 (64%) accepted (Johansson et al., 2014; Lindroos et al., 2019). The DILGOM study was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa. All participants provided written informed consent to participate in the study.

The working participants of the cardiovascular substudy who were at least 55 years old and had an adequate number of valid BP measurements and no missing covariates were included in Study I (n=59).

4.1.3 The Health 2000 study

The Health 2000 study, steered by the National Public Health Institute of Finland, was conducted in 2000–2001, using a random sample of the Finnish population from all over Finland except the Autonomous Territory of the Åland Islands (whole study n=10000, participants aged 30 and over, n=8028) (Aromaa & Koskinen, 2004; Heistaro S, 2008). The participants were involved in a home-visit interview and in a health examination. A restricted number of participants, based on the random availability of monitors, received a sphygmomanometer during the home-visit interview (n=2120) and were instructed to monitor their BP for seven days before their health examination (the Finn-Home Study) (Niiranen et al., 2006). The target population for the Finn-Home Study was 45–74-year-old individuals. The sphygmomanometer and the BP measurement results were returned during the health examination. The Health 2000 study was approved in 1999 by the National Public Health Institute's Ethical Committee and then in 2000 by the Ethical Committee for Research in Epidemiology and Public Health at the Hospital District of Helsinki and Uusimaa (Heistaro S, 2008). All the participants provided written informed consent to participate in the study.

Those with a sufficient number of BP measurements (two on at least two weekdays [Monday, Tuesday, Wednesday, Thursday, Friday] and on both weekend days [Saturday and Sunday]), in full- or part-time employment, with a daytime regular job, and with information on job strain were included in Study III (n=754).

4.2 Measuring blood pressure and pulse wave velocity

4.2.1 Office blood pressure (Studies II, III and IV)

In the FIREA study, the study nurse measured office BP during the clinical visits, using a digital BP monitor (Microlife WatchBP Office Central, Microlife AG, Widnau, Switzerland) (Kollias et al., 2018). The participant was advised to sit for five minutes prior to the measurement and the cuff was applied 1 minute before the measurement. BP was then measured twice with a one-minute break between the measurements and simultaneously on both arms. The average BP of the two measurements taken from the right arm was used for the analyses.

In the Health 2000 study, office BP was measured during the health examination using a standard mercury manometer (Mercuro 300; Speidel & Keller, Jungingen, Germany), usually on the right arm and only exceptionally on the left arm, with a suitable cuff. The participant was asked to sit silently in the measurement room for at least five minutes before the measurement. Altogether two measurements were taken with a two-minute break and their average was used in the analysis.

4.2.2 Home blood pressure (Study III)

In the Health 2000 study, an oscillometric OMRON M4 BP measuring device (Omron Matsusaka Co, Japan, OMRON Healthcare Europe B.V., Hoofddorp, The Netherlands) (Bortolotto et al., 1999) was used for the measurements. The interviewers were taught to measure BP in connection with their other training. The participants were instructed to measure their BP on the upper arm of their nondominant hand and special attention was drawn to the accurate application of the cuff. A precise measurement was ensured by the interviewer first measuring their own BP and the participant then following their example and measuring their own BP.

The measurements were taken in the morning and evening on seven consecutive days (Jula et al., 1999). The participants were directed to sit down in a straight chair by a table for at least 10 minutes, and with the cuff positioned around their upper arm for at least five minutes before the measurement. The participants brought their measurement results and the sphygmomanometer to the health examination. For the main analyses, the mean of morning and evening measurements was used as one day's average BP. In supplementary analyses, the morning and evening values were used separately to examine the day-to-day BP variation.

4.2.3 Ambulatory blood pressure (Studies I and IV)

In the FIREA study, the participants were requested to undergo ABP measurements for 24 hours on a working day. ABP was measured using a Microlife WatchBP O3 Monitor (Microlife AG, Widnau, Switzerland) (Ragazzo et al., 2010) on the individual's nondominant arm. About one minute before each BP measurement, the device sounded an alarm after which the participant was to stop walking, sit down and relax their arm, if possible. If the measurement was unsuccessful, it was repeated instantaneously, until it was successful. BP was measured every 30 minutes over the 24-hour period. The participants reported their bedtime and the time at which they woke up, and average awake and asleep BP were calculated on the basis of this. BP dipping percentage was calculated as [1-(asleep BP/awake BP)]×100. Nondipping was defined as a nocturnal BP reduction of less than 10% (Parati et al., 2014). Only ambulatory measurements episodes that had a sufficient number of valid ABP readings (≥20 awake measurements or ≥7 asleep measurements) were included (Parati et al., 2014).

In the DILGOM study, ABP was measured otherwise identically to the FIREA study method, but on weekdays (i.e. regardless of whether or not it was a working day), and BP was recorded every 20 minutes from 7:00 to 22:00 and every 30 minutes from 22:00 to 7:00.

4.2.4 Pulse wave velocity (Study II)

In the FIREA study, large arterial stiffness was assessed using carotid-femoral PWV measurements performed by a SphygmoCor PVx with an MM3 electronic module and a Millar tonometer (Lindroos et al., 2016). After a five-minute rest in a supine position, three electrodes were attached to the body of the participant to record the timing of cardiac R-wave (time of pulse wave departure from the heart). The pulse waves were measured sequentially at the right common carotid artery and the right femoral artery (time of pulse wave arrival at the distal arteries). The direct distance from the carotid recording site to the suprasternal notch was subtracted from the direct distance between the femoral recording site and the suprasternal notch to obtain the direct distance between the registration points. Transit time was the time delay between the feet of the two waveforms in relation to the R-wave of the simultaneously recorded electrocardiogram (ECG) (Lindroos et al., 2016). PWV was then calculated by dividing the distance by the transit time (m/s). PWV was measured twice and the average of the results was used in the statistical analyses.

4.2.5 Preparation for measurements

In the FIREA study, the participants were requested to abstain from eating, drinking caffeinated drinks and smoking tobacco for three hours and to abstain from consuming alcohol for 24 hours before the PWV measurements. They were also asked to avoid drinking and eating for ten hours, smoking for four hours, consuming alcohol for 24 hours, and strenuous exercise the day before the office BP measurements.

In the Health 2000 study, the participants were requested to avoid eating for four hours, smoking for one hour and physical exercise before the office BP measurements.

4.3 Measuring life stressors

4.3.1 Work-related factors

The JCQ (Karasek et al., 1998) was used to measure job demands and job control and, later, job strain in Studies I-IV. Five items for measuring job demands were: 1) *My job requires working very fast,* 2) *My job requires working very hard,* 3) *I am not asked to do an excessive amount of work,* 4) *I have enough time to get my job done,* and 5) *My job involves conflicting demands*. The items for measuring job control were: 1) *My job allows me to make a lot of decisions on my own*, 2) *My job requires me to be creative*, 3) *My job requires that I learn new things*, 4) *My job involves a lot of repetitive work*, 5) *I have a lot of control over what happens in my job*, 6) *My job requires a high level of skill*, 7) *I get to do a variety of different things in my job*, 8) *I have the opportunity to develop my own special abilities*, and 9) *In my job, I am given a lot of freedom to decide how I do my work*. As the job demands and job control items used in the FIREA study could not all be used with the DILGOM participants, Questions 2), 3) and 4) assessing job demands and Questions 1), 5) and 9) assessing job control were only used in Study I.

Every item had a five-point response scale, which ranged from 1 (I completely agree) to 5 (I completely disagree). The median values for job demands and job control were calculated separately in each study population and based on the results, the participants were placed in either the high job demands group (score above the median) or the low job demands group (score below the median); or in either the low job control group (score below the median) or the high job control group (score above the median). The participants who scored high on job demands and low on job control were placed in the high job strain group, and the remainder of the participants were considered to have low job strain.

Information on occupational title was obtained from Keva for the FIREA study and occupational status was obtained from the DILGOM and Health 2000 studies' surveys. Occupational status was dichotomized in Studies I and IV into manual (e.g. cleaners, maintenance workers) and nonmanual (e.g. teachers, registered nurses) workers, and trichotomized in Study II into manual (e.g. cleaners, maintenance workers), lower-grade nonmanual (e.g. registered nurses, technicians) and higher-grade nonmanual (e.g. teachers, physicians) and in Study III into nonmanual (e.g. specialists, office and client service workers), manual (e.g. farmers, foresters, construction workers), and other workers.

Worktime mode was obtained from the FIREA and DILGOM studies' survey responses and the participants were categorized as having either regular day work or shift work (two- or three-shift work, evening or night work, irregular work).

4.3.2 Private life stressors

In Study II, private life stressors were sleep loss due to worry, serious life events, severe financial difficulties, and caregiving.

Sleep loss due to worry was assessed on the basis of the question from the General Health Questionnaire (Goldberg, 1972), for which participants had to choose their most suitable response: *Have you recently lost much sleep due to worry?* According to their responses, the participants were divided into *yes* (*Rather more than usual* and *Much more than usual*) and *no* (*Not at all* and *No more than usual*) groups.

Serious life events within the past 12 months were assessed by asking the participants whether or not their spouse, child, parent or other family member had been seriously ill or died during the past 12 months (yes or no).

Severe financial difficulties were evaluated by asking the participants whether or not they had faced financial difficulties during the past 12 months (yes or no).

Caregiving was elicited by the following question (yes or no): *Do you provide care to a family member or relative, who is unable to take care of themselves because of age, illness or disability (not including caring for a healthy child)?*

A cumulative sum score was calculated by giving each of the stressors (*job strain, sleep loss due to worry, serious life events, severe financial difficulties or caregiving*) one point and then dividing the participants into groups with scores of 0, 1 and 2 or more points.

4.3.3 Retirement

The participant's working status was confirmed during each study visit and retirement was defined as being on a full-time pension. This information was used to center the data around each participant's real retirement date. There were two potential study waves before and after retirement transition (-2, -1, +1, +2) depending on the obtainable measurements.

4.4 Covariates

Sociodemographic factors. In the FIREA study, year of birth and sex were obtained from Keva's register; in the DILGOM study, year of birth and sex were obtained from the questionnaire responses; and in the Health 2000 study, year of birth was obtained from the register and sex from the questionnaire. In the Health 2000 study, education level was elicited by asking the participants to choose from the following alternatives: low, intermediate or high.

Physical activity. In the FIREA study (Studies I and II), leisure-time physical activity was elicited using a questionnaire (Kujala et al., 1998; Leskinen et al., 2018): The participants were asked how much time they had spent on average per week during the past year on commuting or leisure-time physical activity. Physical activity was classed on four different intensity levels: walking, brisk walking, jogging, or running. Activities corresponding to these in intensity were also considered. The time spent on physical activity had different response options: Not at all, less than 30 minutes, one hour, two to three hours, or four hours or more. Each activity had an average energy expenditure expressed as Metabolic equivalent tasks (MET) and the MET value was multiplied by the time spent on activity at each intensity level in hours. Physical activity was dichotomized into low <14 MET hours/week and active ≥ 14 MET hours/week groups.

In Study IV, a study nurse attached a thigh-worn triaxial Axivity AX3 (Axivity Ltd Newcastle, UK) accelerometer to the participants' right thigh during the clinical study visit. The participants were asked to use the device on at least four days, preferably two working days (before retirement) and two days off. The device was to be worn around the clock and was not to be removed during water-based activities. A custom-made MATLAB program, ACTIPASS (an updated version of Acti4) was used to process the triaxial acceleration data. ACTIPASS uses inclinations and accelerations to define the type and duration of diverse activities with a high sensitivity and specificity (Hettiarachchi et al., 2021; Skotte et al., 2014; Stemland et al., 2015). Daily wake time moderate-to-vigorous physical activity (MVPA) was used as a time-varying covariate in the analyses. MVPA consisted of brisk walking, stair walking, running, cycling, and other physical activities. The total daily time spent on these activities was calculated and averaged for the measurement period.

In the DILGOM study in Study I and in the Health 2000 study in Study III, the participants reported their daily leisure-time physical activity by choosing from the following options (Borodulin et al., 2016): 1) *In my free time, I read, watch TV and do chores that do not involve much exercise and do not stress me physically*, 2) *In my free time, I walk, cycle and exercise in other ways for at least 4 hours a week*, 3) *In my free time, I exercise hard for at least 3 hours a week*, 4) *In my free time, I participate in competitive sports regularly, several times a week*. Categories 2, 3 and 4 were combined in Study I, as were Categories 3 and 4 in Study III.

Smoking. Smoking status was dichotomized into nonsmokers (never and former) and current smokers in all Studies.

Alcohol consumption. Alcohol consumption was defined in the FIREA study in Study II as frequencies of drinking beer, wine and spirits: heavy alcohol consumption was considered >16 drinks per week for women and >24 drinks per week for men (Sillanaukee et al., 1992). In the Health 2000 study in Study III, alcohol consumption was defined as risky if men exceeded the threshold value of ≥288 g per week, or women exceeded the threshold value ≥192 g per week (Sillanaukee et al., 1992).

Sleep. In the FIREA study in Study IV, sleep duration was obtained from the questionnaire responses, as the participants were asked to choose the most suitable alternative for usual sleep duration per 24 hours from the following response options: *6 hours or less, 6.5 hours, 7 hours, 7.5 hours, 8 hours, 8.5 hours, 9 hours, 9.5 hours, 10 hours or more* (Myllyntausta et al., 2019). Sleep duration was used as a time-varying covariate.

Body mass index. BMI was defined as measured weight divided by measured height squared (kg/m^2) in all the cohorts. Reported weight and height were only used if measured values were not available. BMI was used as a continuous variable in Studies I, III and IV. In Study II, BMI was categorized as normal weight (<25.0 kg/m^2), overweight (25 to <30 kg/m^2) and obese (≥30 kg/m^2) (Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation., 2000).

Hypertension. Self-reported hypertension was defined by asking the participants: *Has a doctor ever told you that you have hypertension?* and the response options were: Study II: *yes* [current and former hypertension] or *no* [never hypertension];

Study IV: *yes* [current hypertension] or *no* [former or never hypertension]). In Study III, the participants were asked whether or not they had hypertension and the response options were *yes* or *no*. In Study II, the participants were considered to have hypertension if their SBP was ≥140 mmHg or their DBP was ≥90 mmHg or, when information on BP was missing, if they were on antihypertensive medication. Antihypertensive medication was self-reported by the participants. In Study IV, antihypertensive medication use was elicited separately in each study wave.

Diabetes (Study II) was defined by asking the participants: *Has a doctor ever told you that you have diabetes?* and the response options were *yes* (current or former diabetes) or *no* (never).

4.5 Statistical analyses

The study participants' characteristics were presented as mean ± standard deviations for continuous variables, the number of participants and the percentages for the categorical variables. To examine the potential bias due to selection of the study populations, the characteristics of the participants in each substudy were compared to those of the eligible study populations in all the studies. A t-test was used for continuous variables and the chi-squared test was used for the categorical variables in the comparisons in Studies I and II.

Studies I and II

Analysis of covariance was used to compare differences in ABP by work-related factors in Study I and in large arterial stiffness by life stressors in Study II. The results were then reported as means and 95% confidence intervals (CI).

In Study I, all the analyses were adjusted for age, sex, BMI, antihypertensive medication, physical activity, smoking and cohort. In Study II, adjustments were made sequentially: Model 1 including age and sex, Model 2 including also occupational status, BMI, physical activity, alcohol consumption, smoking and diabetes and Model 3 including also systolic BP.

In Study I, a sensitivity analysis without the participants on antihypertensive medication was conducted to further investigate the association between work-related factors and BP dipping.

As the raw PWV values showed slight skewness to the right in Study II, a log transformation was used for the PWV values.

Study III

Linear regression analysis with generalized estimating equations (GEEs) was used to calculate mean BP separately for weekdays and weekend days by work-related psychosocial stressor. GEE takes into account intra-individual correlation between repeated measurements and is not sensitive to measurements that are missing at random (Diggle et al., 1994). To compare the mean BP change from weekdays to weekend days for each work-related psychosocial stressor, the interaction term *time*work-related psychosocial stressor* was inserted into the GEE model. The interaction term *time*work-related psychosocial stressor*sex* was also added to the GEE model to determine the effects of sex on the variability of home BP during the working week. The day-to-day BP values were adjusted for age, sex and education level. The trend from Monday to Saturday was tested using linear regression analysis with GEEs. The interaction term *work-related psychosocial stressor*time* was used to determine whether the home BP of the entire week was different among the participants with and without work-related psychosocial stressors. The BP changes from weekdays to weekend days by each work-related psychosocial stressor category were adjusted sequentially: first for age, sex, education level, and occupational status and then also for BMI, physical activity, smoking, and alcohol consumption. Furthermore, multivariable-adjusted models were used to separately compare the morning and evening values of weekdays and weekend days. A sensitivity analysis was performed by including only the participants with full-time employment in the GEE model.

Study IV

Linear regression analysis using GEEs was used to calculate the mean ABP values in each study wave (-2, -1, +1 and +2), first in the unadjusted model and then by adjusting for age before retirement and sex. Linear regression analysis with GEEs was used to calculate the BP trend for the entire follow-up from the -2 wave to the +2 wave.

GEE models were also used to calculate BP changes in three periods of time: before retirement (study waves -2 to -1), during the retirement transition (study waves -1 to +1) and after retirement (study waves +1 to +2). To compare the changes between periods, the contrast statements were added to the GEE model. The models were adjusted for sex and age before retirement and BMI, physical activity and sleep duration as time-varying covariates. To directly compare the groups by sex, occupational status, job strain, job demands and worktime mode, the interaction terms *sex*time*, *occupational status*time*, *job strain*time*, *job demands*time* and *worktime mode*time* were added to the GEE model. These analyses were limited to the retirement transition period and the mean differences between study waves -1 and +1 were compared by group.

A sensitivity analysis without the measurements of participants on hypertensive medication in a particular study wave was conducted to further investigate the BP changes around retirement.

SAS software version 9.4 (SAS Institute Inc., Cary, North Carolina, USA) was used to conduct the analyses.

5 Results

5.1 Characteristics of study participants

Table 8 presents the main characteristics of the participants of Studies I–IV. The participants of Studies I, II and IV were retiring individuals and their mean age was higher (mean age 62.2–63.1 years) than that of the participants of Study III (50.9 years), which focused on the working-age population. Moreover, in Studies I, II and IV, the majority of the participants were women (75–90%), whereas in Study III the participants were equally distributed by sex (51% women, 49% men).

Table 8. Characteristics of study participants.

Characteristics	**FIREA and DILGOM, Study I (N= 208)**	**FIREA, Study II (N= 258)**	**Health 2000, Study III (N= 754)**	**FIREA, Study IV (N= 114)**
Age (mean, SD)	62.2 (2.8)	62.4 (1.0)	50.9 (4.8)	63.1 (1.1)
Women (n, %)	157 (75)	212 (82)	381 (51)	103 (90)
Occupational status				
Nonmanual (n, %)	163 (78)	179 (70)	551 (73)	82 (72)
Manual (n, %)	45 (22)	79 (30)	146 (19)	32 (28)
Other (n, %)	NA	NA	57 (8)	NA
BMI (kg/m^2) (mean, SD)	26.5 (4.5)	26.2 (4.4)	26.9 (4.3)	26.3 (4.2)
Current smokers (n, %)	12 (6)	13 (5)	193 (26)	5 (5)
Low physical activity (n, %)	47 (23)	64 (25)	180 (24)	31 (29)
Job strain (n, %)	49 (24)	55 (22)	167 (22)	15 (15)
SBP/DBP (mmHg) (mean, SD)	128.7 (12.1)/ 77.8 (7.2)[a]	137.9 (17.7)/ 83.6 (9.3)	132.3 (17.7)/ 83.8 (10.7)	137.7 (16.5)/ 82.5 (9.3)

[a]BP based on daytime ambulatory BP measurements

SD Standard deviation, *NA* Not applicable, *BMI* Body mass index, *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure

To evaluate the generalizability of the findings, the study samples used were compared to the eligible study populations (the FIREA survey population in Studies I, II and IV, the DILGOM survey population in Study I, and the health examination participants of the Health 2000 study in Study III). In general, the study samples did not differ from the overall study populations in terms of age and sex. However, the FIREA participants in Study IV whose ABP was measured were more often women than the participants whose office BP only was measured or who belonged to the survey population. In addition, the FIREA participants whose BP was measured seemed to have healthier lifestyles and less job strain than the survey participants. The DILGOM participants did not differ from the survey participants in terms of lifestyles nor the Health 2000 study participants from the health examination participants in terms of lifestyles or job strain. More precise selection analyses are presented in the original articles.

5.2 Work-related factors and ambulatory blood pressure (Study I)

The shift workers had significantly higher awake SBP than the regular day workers, (136.5 mmHg, 95% CI 131.9 to 141.1 mmHg vs. 132.5 mmHg, 95% CI 128.3 to 136.6 mmHg, p=0.03), but no difference was observed in asleep SBP or awake or asleep DBP. Furthermore, awake and asleep BP did not differ in terms of other work-related factors, such as occupational status, job demands and job control.

BP dipping had more work-related factor differences and these results are illustrated in **Figure 3**. The participants with low job demands had a significantly larger nocturnal decline in SBP than the participants with high job demands (15.8%, 95% CI 14.0 to 17.6% vs. 14.4%, 95% CI 12.5 to 16.2%, p=0.04). Also, the shift workers had a significantly greater nocturnal decline in DBP than the regular day workers (19.2%, 95% CI 16.9 to 21.5% vs. 17.2%, 95% CI 15.2 to 19.2%, p=0.03) and numerically but not significantly higher SBP dipping than the regular day workers (16.1%, 95% CI 14.1 to 18.0% vs 14.7%, 95% CI 12.9 to 16.4%, p=0.08). The participants with low job demands had borderline higher DBP dipping than the participants with high job demands (18.7%, 95% CI 16.6 to 20.7% vs 17.0%, 95% CI 14.9 to 19.2%, p=0.05). BP dipping did not differ across occupational groups or in terms of job control status.

The sensitivity analysis of 156 participants not on antihypertensive medication revealed no significant BP dipping differences between the groups in terms of occupational status, worktime mode, job demands, or job control. All of the analyses in Study I were adjusted for age, sex, BMI, antihypertensive medication (not used as a covariate in the sensitivity analysis), physical activity, smoking, and cohort.

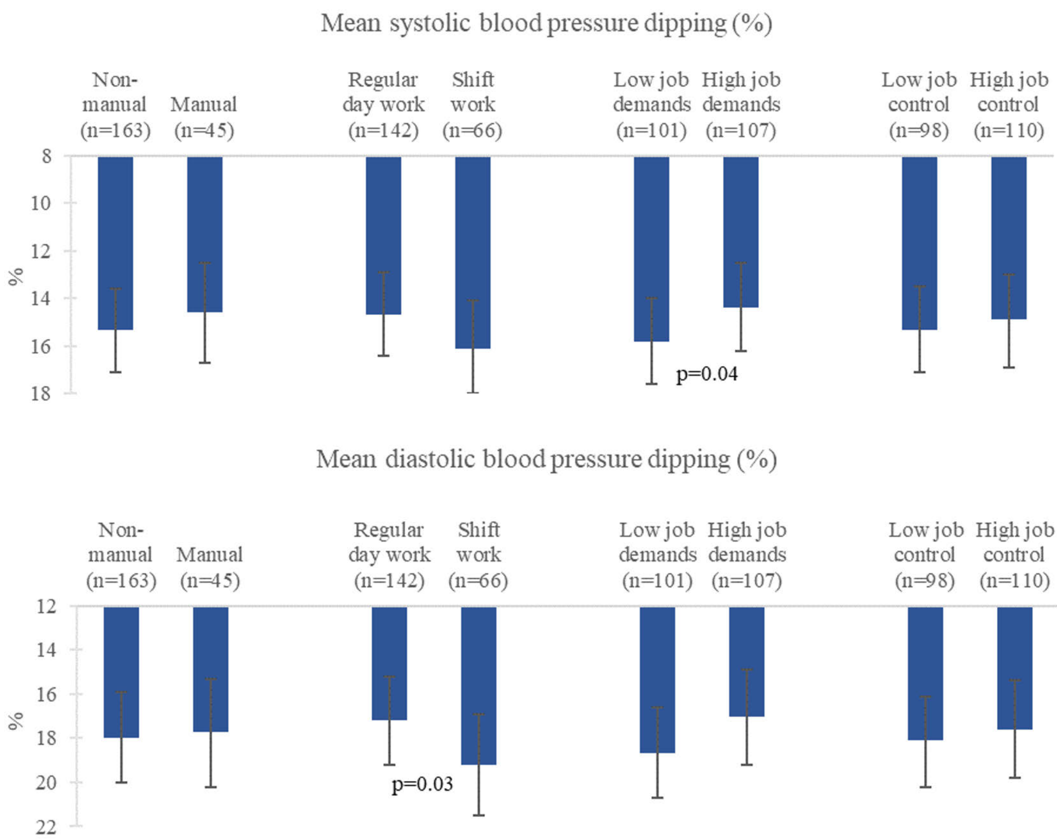

Figure 3. Systolic and diastolic blood pressure dipping by work-related factors. The analyses were adjusted for age, sex, body mass index, use of antihypertensive medication, physical activity, smoking, and cohort. P-values below 0.05 are given.

5.3 Life stressors and large arterial stiffness (Study II)

The proportion of participants who reported life stressors was 4–22% in the study sample. The associations between the various life stressors and PWV were examined in models adjusted for age, sex, occupational status, BMI, physical activity, alcohol consumption, smoking, and diabetes (**Table 9**). The participants with recent illness or death in the family had significantly higher PWV than the participants without (7.93 m/s, 95% CI 7.29 to 8.62 m/s vs. 7.48 m/s, 95% CI 6.99 to 8.01 m/s, p=0.042). In addition, the participants with recent financial difficulties had numerically but not significantly higher PWV than the other participants (8.66 m/s, 7.61 to 9.84 m/s vs. 7.70 m/s, 7.20 to 8.24 m/s, p=0.056). In terms of other life stressors, no relationship was observed between job strain, sleep loss due to worry or caregiving, and PWV. The association between the number of life stressors and PWV was examined. As the number of life stressors increased, PWV also became numerically higher, but this was not statistically significant. Additional adjustment for SBP did not noticeably change the results.

Table 9. Comparison of mean pulse wave velocity (m/s) by different life stressors.

Life stressor	n (%)	Model 1[a] Mean (95% CI)	P value for group difference	Model 2[b] Mean (95% CI)	P value for group difference
Job strain					
No	197 (78)	7.78 (7.25–8.34)	0.94	7.78 (7.26–8.34)	0.86
Yes	55 (22)	7.80 (7.16–8.48)		7.82 (7.19–8.50)	
Sleep loss due to worry					
No	218 (85)	7.78 (7.28–8.33)	0.94	7.79 (7.29–8.33)	0.91
Yes	40 (16)	7.77 (7.13–8.46)		7.76 (7.13–8.45)	
Illness or death in family					
No	200 (82)	7.48 (6.99–8.01)	0.04	7.52 (7.03–8.05)	0.02
Yes	44 (18)	7.93 (7.29–8.62)		8.04 (7.40–8.73)	
Financial difficulties					
No	243 (96)	7.70 (7.20–8.24)	0.06	7.71 (7.21–8.24)	0.06
Yes	11 (4)	8.66 (7.61–9.84)		8.65 (7.62–9.81)	
Caregiver					
No	209 (83)	7.75 (7.23–8.32)	0.82	7.78 (7.26–8.33)	0.50
Yes	43 (17)	7.70 (7.07–8.39)		7.62 (7.01–8.29)	
Total stress			P for trend		P for trend
0	123 (48)	7.73 (7.22–8.29)	0.30	7.74 (7.23–8.28)	0.27
1	87 (34)	7.75 (7.18–8.36)		7.74 (7.18–8.34)	
>1	48 (19)	8.01 (7.38–8.70)		8.04 (7.42–8.72)	

[a]Model 1: adjusted for age, sex, occupational status, body mass index, physical activity, alcohol consumption, smoking and diabetes, [b]Model 2: additionally adjusted for systolic blood pressure. *CI* Confidence interval

5.4 Work-related psychosocial stressors and day-to-day blood pressure variation (Study III)

When daily home BP was adjusted for age, sex, and education level, SBP and DBP seemed to be at its highest on Monday and at its lowest on Saturday. The BP trends from Monday to Saturday were statistically significant among those with and without work-related psychosocial stressors ($p < 0.0001$), but no work-related psychosocial stressor*time interaction was observed (**Figure 4**). Respectively, the SBP and DBP levels increased from Saturday to Sunday and further increased from Sunday to Monday among those with and without work-related psychosocial stressors. The only exception was DBP in the high job strain group: DBP remained stable from Saturday to Sunday, but increased from Sunday to Monday.

The weekday and weekend day SBP and DBP values did not differ in terms of work-related psychosocial stressors. However, a comparison of weekday and weekend day BP values (**Table 10**) showed that among the participants with high job strain, SBP and DBP decreased significantly more from weekdays to weekend days than among the participants without job strain (mean differences -1.1 mmHg, 95% CI -2.2 to -0.1 mmHg for SBP; -1.0 mmHg, 95% CI -1.7 to -0.4 mmHg for DBP). In addition, among the participants with high job demands, SBP and DBP decreased significantly more from weekdays to weekend days than among the participants with low job demands (mean differences -0.9 mmHg, 95% CI -1.7 to -0.1 mmHg for SBP; -0.6 mmHg, 95% CI -1.1 to -0.1 mmHg for DBP). In contrast, BP values declined similarly from weekdays to weekend days regardless of the level of job control. When the morning and evening values were analyzed separately, differences were observed in the BP changes from weekdays to weekend days in the morning values but not in the evening values (**Tables 11a and 11b**).

To examine the role of part-time work in the results, the analyses were repeated this time excluding part-time workers. However, this had no impact on the results. Moreover, to determine whether sex modified the association between work-related psychosocial stressors and home BP during the working week, the interaction term *time*work-related psychosocial stressor*sex* was added to the model. However, the differences between weekday and weekend day BPs concerning work-related psychosocial stressors did not depend on sex. Age, sex, education level, occupational status, BMI, physical activity, smoking, and alcohol consumption were adjusted for both in the main analyses and in the analyses studying only full-time workers and the effect of sex on the results.

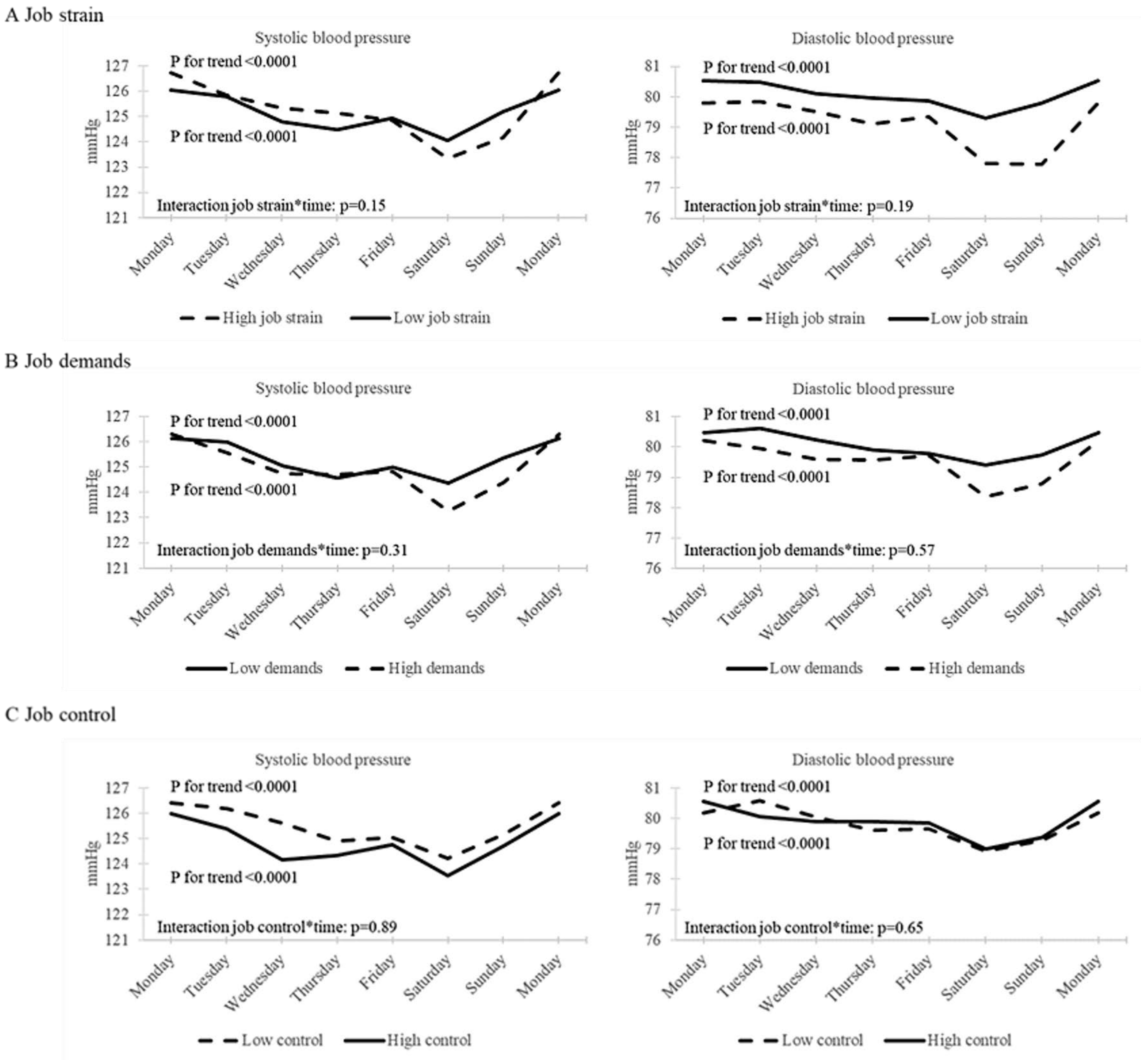

Figure 4. Day-to-day variation of systolic and diastolic blood pressure by a) job strain, b) job demands and c) job control. Analyses were adjusted for age, sex and education level. The trend test was conducted from Monday to Saturday.

Table 10. Mean weekday BP, mean BP changes from weekdays to weekend days and mean differences between BP changes from weekdays to weekend days by work-related psychosocial stressors.

Work-related psychosocial stressor	**BP**	**Weekday BP (mmHg) Mean (95% CI)**	**BP changes from weekdays to weekend days (mmHg) Mean (95% CI)**	**Difference between BP changes of groups (mmHg) Mean (95% CI)**	**P for interaction time*work-related psychosocial stressor**
Job strain					
Low	**Systolic**	127.8 (125.6 to 130.0)	-0.7 (-1.1 to -0.2)	-1.1 (-2.2 to -0.1)	0.04
High		129.3 (126.3 to 132.4)	-1.8 (-2.7 to -0.8)		
Low	**Diastolic**	81.5 (80.2 to 82.8)	-0.7 (-1.0 to -0.4)	-1.0 (-1.7 to -0.4)	0.003
High		81.6 (79.9 to 83.3)	-1.7 (-2.3 to -1.1)		
Job demands					
Low	**Systolic**	128.2 (125.9 to 130.4)	-0.5 (-1.1 to 0.0)	-0.9 (-1.7 to -0.1)	0.04
High		128.2 (125.6 to 130.8)	-1.4 (-2.0 to -0.8)		
Low	**Diastolic**	81.6 (80.3 to 82.9)	-0.6 (-1.0 to -0.3)	-0.6 (-1.1 to -0.1)	0.02
High		81.4 (79.9 to 82.8)	-1.3 (-1.6 to -0.9)		
Job control					
Low	**Systolic**	128.9 (126.5 to 131.3)	-0.9 (-1.5 to -0.3)	0.04 (-0.8 to 0.9)	0.92
High		127.1 (124.6 to 129.5)	-0.9 (-1.5 to -0.3)		
Low	**Diastolic**	81.8 (80.4 to 83.2)	-0.9 (-1.3 to -0.5)	-0.03 (-0.6 to 0.5)	0.91
High		81.1 (79.7 to 82.5)	-0.9 (-1.3 to -0.6)		

Analyses were adjusted for age, sex, education level, occupational status, BMI, physical activity, smoking and alcohol consumption. *BP* Blood pressure *CI* Confidence interval

Table 11a. Mean morning weekday BP, mean morning BP changes from weekdays to weekend days and mean differences between morning BP changes from weekdays to weekend days by work-related psychosocial stressors.

Work-related psychosocial stressor	BP	Weekday BP (mmHg) Mean (95% CI)	BP changes from weekdays to weekend days (mmHg) Mean (95% CI)	Difference between BP change of groups (mmHg) Mean (95% CI)	P for interaction time*work-related psychosocial stressor
Job strain					
Low	**Systolic**	125.8 (123.4 to 128.2)	-0.5 (-1.1 to 0.1)	-1.5 (-2.9 to -0.1)	0.03
High		127.5 (124.2 to 130.9)	-2.0 (-3.3 to -0.8)		
Low	**Diastolic**	81.2 (79.8 to 82.6)	-0.6 (-1.0 to -0.3)	-1.2 (-2.0 to -0.4)	0.005
High		81.5 (79.7 to 83.2)	-1.8 (-2.6 to -1.1)		
Job demands					
Low	**Systolic**	126.1 (123.7 to 128.6)	-0.2 (-0.9 to 0.5)	-1.4 (-2.5 to -0.3)	0.01
High		126.3 (123.5 to 129.1)	-1.6 (-2.4 to -0.8)		
Low	**Diastolic**	81.4 (79.9 to 82.8)	-0.7 (-1.1 to -0.2)	-0.5 (-1.2 to 0.2)	0.13
High		81.1 (79.5 to 82.6)	-1.2 (-1.7 to -0.7)		
Job control					
Low	**Systolic**	127.0 (124.4 to 129.6)	-1.0 (-1.7 to -0.2)	0.2 (-0.9 to 1.3)	0.70
High		125.1 (122.5 to 127.8)	-0.7 (-1.5 to -0.0)		
Low	**Diastolic**	81.6 (80.1 to 83.1)	-1.1 (-1.6 to -0.6)	0.4 (-0.3 to 1.1)	0.25
High		80.8 (79.3 to 82.3)	-0.7 (-1.1 to -0.3)		

Analyses were adjusted for age, sex, education level, occupational status, BMI, physical activity, smoking and alcohol consumption. *BP* Blood pressure, *CI* Confidence interval

Table 11b. Mean evening weekday BP, mean evening BP changes from weekdays to weekend days and mean differences between evening BP changes from weekdays to weekend days by work-related psychosocial stressors.

Work-related psychosocial stressor	BP	Weekday BP (mmHg) Mean (95% CI)	BP changes from weekdays to weekend days (mmHg) Mean (95% CI)	Difference between BP changes of groups (mmHg) Mean (95% CI)	P for interaction time*work-related psychosocial stressor
Job strain					
Low	**Systolic**	128.8 (126.4 to 131.1)	-0.9 (-1.5 to -0.3)	-0.4 (-1.6 to 0.9)	0.56
High		130.0 (127.0 to 133.1)	-1.2 (-2.3 to -0.1)		
Low	**Diastolic**	81.1 (79.7 to 82.4)	-0.8 (-1.2 to -0.4)	-0.6 (-1.3 to 0.2)	0.14
High		81.1 (79.3 to 82.8)	-1.4 (-2.0 to -0.7)		
Job demands					
Low	**Systolic**	129.2 (126.8 to 131.6)	-0.9 (-1.6 to -0.2)	-0.2 (-1.2 to 0.9)	0.75
High		129.0 (126.3 to 131.6)	-1.0 (-1.8 to -0.3)		
Low	**Diastolic**	81.2 (79.8 to 82.6)	-0.7 (-1.2 to -0.3)	-0.5 (-1.1 to 0.2)	0.15
High		80.9 (79.4 to 82.4)	-1.2 (-1.6 to -0.7)		
Job control					
Low	**Systolic**	129.9 (127.4 to 132.4)	-0.8 (-1.5 to -0.1)	-0.2 (-1.3 to 0.8)	0.65
High		127.9 (125.4 to 130.5)	-1.1 (-1.8 to -0.3)		
Low	**Diastolic**	81.3 (79.8 to 82.8)	-0.7 (-1.1 to -0.2)	-0.5 (-1.1 to 0.2)	0.15
High		80.6 (79.1 to 82.1)	-1.2 (-1.6 to -0.7)		

Analyses were adjusted for age, sex, education level, occupational status, BMI, physical activity, smoking and alcohol consumption. *BP* Blood pressure, *CI* Confidence interval

5.5 Retirement transition and ambulatory blood pressure (Study IV)

Figure 5 shows the unadjusted levels of systolic and diastolic ABP and BP dipping values during study waves in relation to retirement. The post-retirement awake SBP and DBP and BP dipping values were lower than the pre-retirement levels. The asleep SBP and DBP values were stable around the retirement transition.

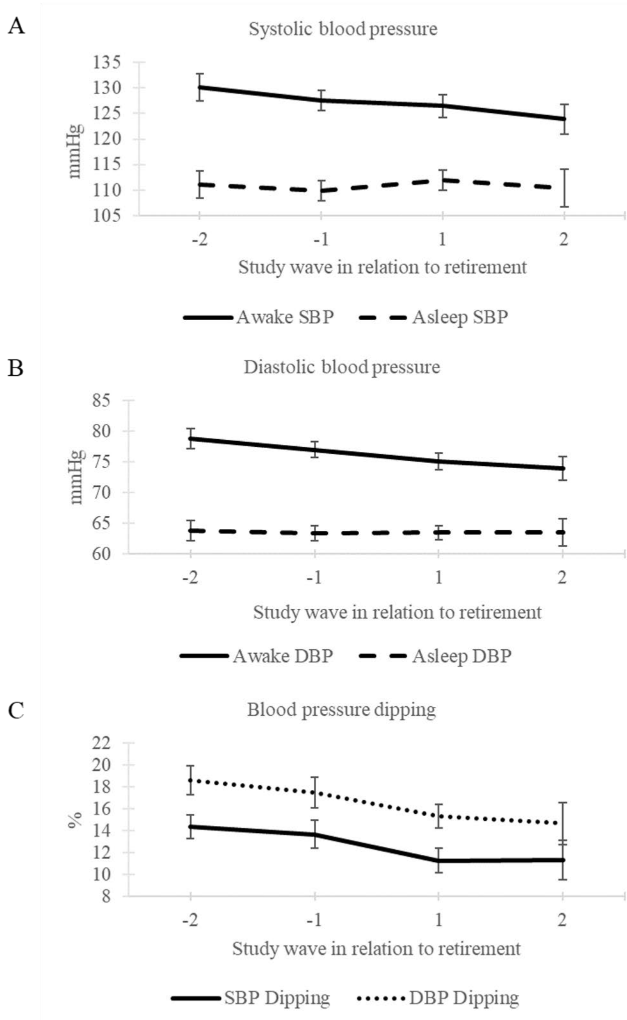

Figure 5. Unadjusted ambulatory A) systolic BP, B) diastolic BP, and C) BP dipping values at each study wave before and after retirement transition. *SBP* Systolic blood pressure, *DBP* Diastolic blood pressure

Table 12 presents the multivariable-adjusted changes in ABP before, during and after the retirement transition. Awake SBP decreased before (-5.4 mmHg, 95% CI -8.2 to -2.5 mmHg) and after the retirement transition (-3.6 mmHg, 95% CI -6.4 to -0.8 mmHg) but remained stable during the transition. The change in BP during the retirement transition was only numerically but not significantly different from the change in BP before the transition (p=0.077), but no differences were observed in changes in BP during and after the transition.

Awake DBP decreased before (-3.1 mmHg, 95% CI -4.8 to -1.5 mmHg), during (-2.3 mmHg, 95% CI -3.6 to -0.9 mmHg) and after the retirement transition (-2.4 mmHg, 95% CI -4.0 to -0.7 mmHg). The change before, during and after retirement transition was similar. When the trend of the entire follow-up was tested, both awake SBP and awake DBP showed a significantly decreasing trend from before to after the retirement transition (-1.0 mmHg per year, 95% CI -1.7 to -0.3 mmHg for SBP and -1.1 mmHg per year, 95% CI -1.5 to -0.7 mmHg for DBP).

Asleep SBP increased significantly during the retirement transition (2.4 mmHg, 95% CI 0.4 to 4.4 mmHg) but remained stable before and after. The change in asleep SBP before the transition differed numerically but not significantly from the change during the retirement transition (p=0.074), whereas the change in BP after the retirement transition deviated significantly from the change in BP during it (p=0.016). Asleep DBP did not change before, during or after the transition. There was no trend in asleep SBP or asleep DBP throughout follow-up.

Finally, SBP dipping decreased significantly before (-2.1 mmHg, 95% CI -3.9 to -0.3 mmHg) and during (-3.0 mmHg, 95% CI -4.7 to -1.3 mmHg) the retirement transition but not after it. DBP dipping decreased during the retirement transition (-2.4 mmHg, 95% CI -4.2 to -0.6 mmHg) but not before or after it. There were no differences between SBP or DBP dipping during, before or after the transition. However, SBP and DBP dipping showed a significantly decreasing trend throughout follow-up from pre-retirement to post-retirement (-0.9 mmHg per year, 95% CI -1.3 to -0.5 mmHg for SBP and -1.1 mmHg per year, 95% CI -1.6 to -0.5 mmHg for DBP).

Table 12. Mean changes in ambulatory BP (mmHg) and BP dipping (%) values before, during and after retirement transition.

	Awake SBP (mmHg) Mean (95% CI)	**Awake DBP (mmHg) Mean (95% CI)**	**Asleep SBP (mmHg) Mean (95% CI)**	**Asleep DBP (mmHg) Mean (95% CI)**	**SBP dipping (%) Mean (95% CI)**	**DBP dipping (%) Mean (95% CI)**
Change before retirement (wave -1 vs -2)	-5.4 (-8.2 to -2.5)	-3.1 (-4.8 to -1.5)	-1.8 (-4.8 to 1.2)	-1.0 (-2.8 to 0.9)	-2.1 (-3.9 to -0.3)	-2.1 (-4.2 to 0.06)
Change during retirement transition (wave +1 vs -1)	-1.6 (-3.8 to 0.6)	-2.3 (-3.6 to -0.9)	2.4 (0.4 to 4.4)	0.1 (-1.2 to 1.4)	-3.0 (-4.7 to -1.3)	-2.4 (-4.2 to -0.6)
Change after retirement (wave +2 vs +1)	-3.6 (-6.4 to -0.8)	-2.4 (-4.0 to -0.7)	-2.4 (-5.7 to 0.9)	-1.0 (-3.3 to 1.3)	-0.4 (-3.3 to 2.5)	-1.3 (-4.4 to 1.9)
P for before vs. during retirement	0.077	0.51	0.074	0.44	0.53	0.84
P for after vs. during retirement	0.23	0.95	0.016	0.42	0.14	0.58
P for trend throughout follow-up	0.004	<0.0001	0.320	0.866	<0.0001	<0.0001

Analyses were adjusted for sex and age before retirement and body mass index, physical activity and sleep duration as time-varying covariates. *BP* Blood pressure, *SBP* Systolic blood pressure, *CI* Confidence interval, *DBP* Diastolic blood pressure

To further investigate the association between the retirement transition and BP without the modifying effects of BP medication, a sensitivity analysis of only the participants not on antihypertensive medication (n=82) was conducted. These results mostly resembled the results of the main analysis. However, in the limited study population, awake DBP remained stable after the transition (-2.6 mmHg, 95% CI -5.3 to 0.2 mmHg).

Finally, analyses were performed to determine whether the changes in ABP and BP dipping around the retirement transition depended on sex, occupational status, job strain, job demands or worktime mode. Only worktime mode was associated with significant changes in ABP and BP dipping during the retirement transition. The change in asleep SBP and DBP was greater during the transition among the shift workers than among the regular day workers (5.2 mmHg, 95% CI -0.4 to 10.8 mmHg vs 1.6 mmHg, 95% CI -0.2 to 3.3 mmHg, p for interaction 0.023 for SBP; 2.3 mmHg, 95% CI -0.6 to 5.1 mmHg vs -0.2 mmHg, 95% CI -1.6 to 1.2 mmHg, p for interaction 0.024 for DBP). Similar differences were observed for DBP dipping (-5.9 mmHg, 95% CI -9.2 to -2.7 mmHg vs -1.0 mmHg, 95% CI -2.9 to 0.9 mmHg, p for interaction 0.014). No difference was observed between the awake SBP or DBP or SBP dipping of the shift workers and the regular day workers during the retirement transition.

No differences in the ABP and BP dipping values during retirement transition were observed in the groups in terms of sex, occupational status, job strain and job demands.

6 Discussion

6.1 Work-related factors and ambulatory blood pressure (Study I)

In Study I, the shift workers manifested significantly higher awake SBP than the regular day workers but there were no differences between their diastolic awake BP and asleep SBP and DBP. Moreover, the shift workers had significantly higher DBP dipping, and numerically but not significantly higher SBP dipping than the regular day workers. The participants with low job demands had significantly higher SBP dipping and borderline higher DBP dipping than the participants with high job demands. Occupational status, job demands or job control were not related to awake and asleep SBP and DBP. No differences were found in BP dipping based on occupational or job control status. The differences in BP dipping values were attenuated when the analysis excluded participants who were on antihypertensive medication.

Ohira et al. studied 20- to 45-year-old men working in a nuclear power plant and the results resembled those of Study I, as awake SBP in both studies was higher among shift workers than regular day workers. Similarly, the awake DBP and the asleep SBP and DBP of the shift workers and regular day workers did not differ in these studies. As Study I did not examine the differences between ABP in specific professions, the job descriptions of the shift workers and regular day workers were different in the study by Ohira et al. Moreover, the adjustments were partly different between these two studies. In addition, the study by Ohira et al. included young Japanese men and had no participants who were on antihypertensive medication or had certain illnesses. Consequently, on the basis of the results of Study I and the study by Ohira et al. we can speculate that the higher awake SBP among the shift workers than among the regular day workers may be a wider phenomenon concerning not only Western aging workers but also Asian younger workers. Two (Fialho et al., 2006; Lo et al., 2008) of three (Fialho et al., 2006; Lo et al., 2008; Munakata et al., 2001) earlier studies have found that evening and night shifts and long shifts are unfavorable for ABP profiles. However, as these studies examined the differences between ABP on different shifts for each employee, it is difficult to compare them to Study I.

Three (Kitamura et al., 2002; Lo et al., 2008; Yamasaki et al., 1998) of four (Fialho et al., 2006; Kitamura et al., 2002; Lo et al., 2008; Yamasaki et al., 1998) earlier studies have reported that shift work is associated with unfavorable changes in BP dipping profiles. However, these studies have mostly examined younger individuals than Study I and studied nurses, medical residents and factory employees. Moreover, only one study (Yamasaki et al., 1998) has compared evening and night shift workers to day-shift workers, as in Study I, and the other studies have focused on within-individual changes in ABP profiles during rotating shifts. Yamasaki et al. found that evening and night shift workers more often manifested higher asleep SBP and thus, SBP nondipping than the day-shift workers. In contrast Study I found that the shift workers had greater BP dipping, but that this was due to higher awake SBP and DBP values than those among the regular dayworkers. The worktime mode was related to BP dipping differently in these two studies, but this could be result of the differences between the participants in these studies. The participants in the study by Yamasaki et al. were female nurses aged 30–59 and individuals who were on antihypertensive medication or had a history of cardiovascular disease were excluded. More importantly, in the study by Yamasaki et al. the majority of shift workers worked nightshifts whereas in Study I nightshift workers were rare. A few studies using different study sets to Study I promote the finding of shift work's unfavorable effect on BP dipping (Kitamura et al., 2002; Lo et al., 2008).

Several mechanisms may potentially explain the findings of Study I. Shift workers have also been found to sleep less than day workers, manifest higher anger-in (anger held in or suppressed) scores and to possibly have more sympathetic nerve activity (Ohira et al., 2000). Shift work increased awake SBP in Study I, but as the majority of shift workers were resting during the night, the effect of BP dipping was adequate. As it has been earlier speculated that circadian misalignment causes higher BP values among shift workers (Morris et al., 2017), and that their short sleep duration increases their ambulatory SBP (Shulman et al., 2018), night shift workers may be at an increased risk of cardiovascular diseases.

Earlier studies (Brown et al., 2006; Fan et al., 2013) have not found an association between job demands and ABP. As these studies included only participants who were not on antihypertensive medication, their results are in line with the results of the sensitivity analysis in Study I. However, Study I's finding that in the whole study population, low job demands were related to higher BP dipping than high job demands, emphasizes the work environment's role in reducing the risk of cardiovascular disease.

The ABP or BP dipping values of the groups with high or low job control did not differ. However, one earlier study found that male participants with low job control had higher asleep SBP and lower SBP dipping than participants with high job control (Fan et al., 2013). Another study found that among aging workers, a high possibility for development and high influence at work were associated with somewhat higher ABP (Mc Carthy et al., 2014). However, Fan et al. had slightly different inclusion criteria than Study I, and Mc Carthy et al. evaluated job control using a high possibility for development and high influence at work, which are components of the COPSOQ and not the JCQ.

The exclusion of participants using antihypertensive medication generally improved the BP dipping values and eliminated the between-group differences. It is likely that the participants on antihypertensive medication manifested inferior BP dipping values than the participants who were not on antihypertensive medication. More importantly, according to the results of Study I, regular day work and high job demands could be a risky combination, especially for the cardiovascular safety of the workers on antihypertensive medication. However, the awake BP values of the participants not on antihypertensive medication were not studied. Thus, the awake BP values of the shift workers on antihypertensive medication may have formed the main contribution to the higher awake BP values, making their cardiovascular risk this way slightly higher than that of the regular day workers.

Some limitations need to be considered when interpreting the findings of Study I. Although the proportion of shift workers was 32%, the number of night-time workers remained low, which made it difficult to study the association between night work and ABP. Moreover, using information on sleep quality as a covariate during ABP monitoring could have elaborated the results. Finally, work-related psychosocial stressors were assessed using the shortened version of the widely used JCQ. However, the shortened version of the JCQ has shown to correlate with the complete questionnaire (Fransson et al., 2012).

6.2 Life stressors and large arterial stiffness (Study II)

In Study II, the participants with recent illness or death in the family or recent financial difficulties had higher PWV values than the participants without these risk factors. Job strain, sleep loss due to worry and caregiving were not related to the PWV values. As the stress sum increased, the PWV values also became numerically higher. Similarly, Bomhof-Roordink et al. showed that recent negative life events such as serious illness or injury, death of a close friend or relative, and major financial loss were associated with increased large arterial stiffness evaluated by central AIx (Bomhof-Roordink et al., 2015). However, the study sample of Bomhof-Roordink et al. differed from the sample of Study II in terms of age and possibly disease history: About 29% of the participants had suffered from depression or anxiety in the last month and about 44% had remitted depression or anxiety

(Bomhof-Roordink et al., 2015). Bomhof-Roordink et al. also studied the association between overall negative life events and large arterial stiffness, not between one particular negative life event and large arterial stiffness.

To my knowledge, this is the first study to examine the relation between recent death or illness in the family and the gold standard of large arterial stiffness evaluation: carotid-femoral PWV. However, earlier studies have found that individuals who have lost a significant person are at an increased risk of cardiovascular events and diseases (Carey et al., 2014; Graff et al., 2016; Li et al., 2002; Mostofsky et al., 2012; Wei et al., 2023). The mechanism between bereavement in the family and increased large arterial stiffness remains unclear. However, inflammation and oxidative stress have been linked to the development of large arterial stiffness (Palombo & Kozakova, 2016) and stress has been found to associate with inflammation and oxidative stress (Lagraauw et al., 2015). These processes could therefore mediate the incremental effects of stress induced by bereavement on large arterial stiffness.

The finding that recent financial difficulties were associated with increased large arterial stiffness was novel, as earlier evidence on the same subject is lacking. However, a previous meta-analysis and study have shown that individuals with lower income have higher prevalence of cardiovascular risk factors such as hypertension, and higher risk of cardiovascular diseases, strokes, and cardiovascular deaths (Khaing et al., 2017; Minhas et al., 2023). The mechanisms that link stress to cardiovascular diseases could be dysregulation of the hypothalamus-pituitary-adrenal cortex axis, changes in the autonomic nervous system response, and inflammation (Kivimäki & Steptoe, 2018).

Study II found that job strain, caregiving and sleep loss due to worry were not associated with increased large arterial stiffness. Similarly, Massamba et al. did not observe any associations between job strain, ERI and large arterial stiffness measured by carotid-femoral PWV in their prospective study population until the participants were classified according to their BP values. High job strain with high baseline DBP seemed to increase large arterial stiffness while high job strain with low baseline DBP and high effort-reward imbalance with high baseline SBP did the opposite. However, most earlier studies have found that job strain is unfavorable for large arterial stiffness (Bomhof-Roordink et al., 2015; Kaewboonchoo et al., 2018; Michikawa et al., 2008; Nomura et al., 2005; Otsuka et al., 2009; Utsugi et al., 2009). There are numerous possible reasons for these conflicting results: Various methods for measuring PWV (Milan et al., 2019; R. R. Townsend, 2016), study samples with different ages, and potential differences in large arterial stiffness between European and Asian populations (Park et al., 2022). Although caregiving was not related to increased large arterial stiffness in Study II, some earlier studies have found that a relationship exists between caregiving and an increased risk of cardiovascular diseases but only in the case of more intense levels of caregiving (Capistrant et al., 2012; Lambrias et al., 2023).

Study II found no association between sleep loss due to worry and increased large arterial stiffness. This was somewhat surprising, as recent studies have found insomnia and poor sleep quality to be related to increased large arterial stiffness evaluated by PWV (Pan et al., 2022; Sunbul et al., 2022). In addition, low sleep quality but not sleep duration itself has been associated with increased large arterial stiffness evaluated by AIx among post-menopausal women (Lee et al., 2021). Similarly, impaired sleep duration and insomnia have been associated with an increased risk of cardiovascular diseases and hypertension (Bathgate & Fernandez-Mendoza, 2018; Covassin & Singh, 2016; Schwartz et al., 1999). However, sleep loss due to worry was elicited by a single question in Study II and the other studies elicited sleep quality using three questions from the Berlin questionnaire, the Pittsburgh sleep quality index and the Insomnia Severity Index (Lee et al., 2021; Pan et al., 2022; Sunbul et al., 2022). More importantly, the large arterial stiffness was measured by methods other than carotid-femoral PWV. Two of the studies included participants suffering from insomnia (Pan et al., 2022; Sunbul et al., 2022) whereas the Study II population consisted of aging workers. Consequently, perhaps no relation between sleep loss due to worry and large arterial stiffness was observed in Study II, as only more intense sleep difficulties affect large arterial stiffness. Moreover, as the question in Study II required sleep loss to be due to worries, the participants who had sleep loss for other reasons more likely provided a negative response and this may have diminished the differences in large arterial stiffness between these two groups. Earlier research on the relation between bereavement, financial difficulties, caregiving, and large arterial stiffness is nonexistent.

The finding of Study II that individuals with multiple stressors have higher large arterial stiffness than individuals with no stressors or one stressor, needs further research in a longitudinal study with larger samples. Moreover, the relation between an increasing number of life stressors and cardiovascular diseases has rarely been earlier studied (Albert et al., 2013, 2017; Rosengren et al., 2004).

A strength of Study II was that it used SBP as a covariate, as PWV is known to correlate with SBP (Mancia et al., 2023).

6.3 Work-related psychosocial stressors and day-to-day blood pressure (Study III)

Study III was based on home BP over an entire week. The participants with high job strain and high job demands showed a greater decrease in home BP from weekdays to weekend days than the participants with low job strain or low job demands. No difference was observed between the home BP values of those with and without job control nor between full-time and part-time-workers. The results were mostly driven by morning values.

A few studies have earlier examined differences between ABP values during working hours and leisure time. Job strain and ERI have been associated with higher ABP values not only during working hours, but also during leisure time and night-time on a working day (Clays et al., 2007; Schnall et al., 1998; Vrijkotte et al., 2000). As the morning BP values were more strongly associated with job strain and job demands in Study III, work-related psychosocial stressors truly seem to affect leisure-time BP values. However, whether the effect is stronger at certain times of the day remains unclear. As the participants of Study III worked regular daytime jobs, the morning measurement may have been rushed and this may have affected the BP values. Conversely, as the evening measurements were taken several hours after the working day, the effect of work-related psychosocial stressors on home BP may have been impaired at the time of the evening measurements. In general, work-related psychosocial stressors seemed to have a short-term effect on home BP, as the differences between the groups became established over the one-week BP monitoring.

Six studies have examined differences between ABP on working days and on days off. Like the decreasing trend in home BP from Monday to Saturday found in Study III, five earlier studies (Del Arco-Galan et al., 1994; Enström & Pennert, 1996; Goldstein et al., 1999; Riese et al., 2004; Vrijkotte et al., 2000) have found that ABP values are higher during working days than during days off work. Contrary to this, one study (Goldstein et al., 1992) observed no differences between ABP values on working days and days off. As the participants in the study by Enström & Pennert were aged 41–64 and worked in various occupations, these findings are comparable to those of Study III that suggested that working days have an unfavorable effect on the BP of middle-aged workers. The rest of the studies had a relatively large scale of participant age (range 20–55 years), had more limited sample sizes (30–159 participants) and included mainly healthcare professionals. This makes comparing these studies and Study III challenging. More importantly, the above studies focused on studying ABP on single days, while in Study III home BP was monitored for an entire week. Moreover, three of the five earlier studies included only men or only women in the studies. However, as no differences were observed between women and men in the main analysis of Study III, this fact does not limit interpretation of the results.

Regarding home BP, working individuals had higher BP values at the beginning of the week than during the weekend (Juhanoja et al., 2016). Moreover, when ABP was recorded on the third consecutive day of morning shifts and on the second consecutive day off, job strain was not associated with ABP (Riese et al., 2004). However, high job demands associated with a higher systolic ABP during a working day (Riese et al., 2004). As regards high decision latitude (combination of skill discretion and decision authority), high job demands were also associated with higher DBP at work (Riese et al., 2004). The finding of Study III that home BP decreased more from weekdays to weekend days among the participants with high job demands than among the participants with low job demands was partly consistent with the finding of Riese et al.. However, in Study III, job strain was also associated with differences between home BP on weekdays and weekend days. As the sample in the study by Riese et al. included healthy nurses with a mean age of 35.9 years and Study III included slightly older participants with more widely ranging occupations, high job demands specifically seem to have a certain degree of effect on BP.

Another Dutch study (Vrijkotte et al., 2000) discovered that high imbalance but not overcommitment was related to higher ambulatory SBP values during both working days and days off, but found no relation between work-related psychosocial stressors and ambulatory DBP. As the imbalance and overcommitment measured by ERI does not completely overlap with the demands and control measured by the JCQ, the study by Vrijkotte et al. adds information on the association between work-related psychosocial stressors and awake BP.

Study III had some strengths and limitations. As low occupational status and low education level have been found to impair the ABP profile of workers (Brown et al., 2006; Clays et al., 2011; Landsbergis et al., 2003b), using occupational status and education level as covariates increased the methodological quality of Study III. Moreover, the study sample did not differ from the health examination participants in terms of BP, lifestyles or work-related psychosocial stressors. Consequently, the results represent Finnish workers well. The study of morning and evening values separately offered further information on the association between work-related psychosocial stressors and home BP. However, as people with sleep apnea have higher morning BP values than evening BP values (Johansson, Niiranen, et al., 2011), and people with insomnia or long sleeping times (≥9 hours) have higher morning–evening home BP variability (Johansson, Kronholm, et al., 2011), further studies should adjust for sleep apnea status and sleeping time. Moreover, although the participants were required to have a regular job, they were not obliged to work from Monday to Friday or to have days off work on Saturday and Sunday. Furthermore, information on daily activities and working hours was not available. The participants were not blinded for the BP measurement results as they self-recorded their home BP values on the supplied forms. Additionally, as the participants measured their BP at home instead of their ABP, information on the association between work-related stressors and changes in BP dipping during the working week was missing.

6.4 Retirement transition and ambulatory blood pressure (Study IV)

In Study IV, awake SBP decreased before and after the retirement transition but remained stable during it. Awake DBP decreased before, during and after the transition. Asleep SBP was stable before and after the retirement transition and increased during it, whereas asleep DBP was stable before, during and after the retirement transition. SBP dipping decreased before and during the retirement transition and stabilized after it, whereas DBP dipping was stable before and after the transition and decreased during it. The results of the participants who were not on antihypertensive medication were mainly comparable to the results of the whole study sample.

Earlier Chinese studies have reported that retirement transition is associated with beneficial changes in office BP (Q. Wang, 2020; Xue et al., 2017), but the results of Study IV did not replicate these findings, as no significant changes in office BP were found. However, the comparison of the results of the Chinese studies to those of Study IV is complicated by differences in working cultures and circumstances, BP levels (NCD Risk Factor Collaboration (NCD-RisC), 2017) and the lower retiring age in China than in Finland. Another study with a follow-up of a few years (Ekerdt et al., 1984) found that systolic and diastolic office BP increased more among retiring men than among working men, though hypertension incidence did not increase more among the retirees than among the workers. Although the results of the study by Ekerdt et al. were more comparable to the results of Study IV, the study samples differed from each other as the former excluded participants with chronic medical conditions or high BP (SBP over 140 mmHg or DBP over 90 mmHg). However, both studies found that the retirement transition was more unfavorable than beneficial for the BP of aging workers in Western countries. In the future, it would be interesting to compare retiring individuals' ABP profiles to those of working individuals.

Awake and asleep SBP deviated from the pre- and post-retirement trends during the retirement transition. The transition to retirement is a life change that can involve psychological stress, which could in turn affect BP via the sympathetic nervous system, the hypothalamic–pituitary–adrenocortical axis, unhealthy lifestyle, or mental distress (Munakata, 2018). Although the regulation of BP is different during daytime and night-time (Smolensky et al., 2017), the retirement transition seems to affect awake and asleep BP in the same manner. As SBP usually tends to increase and DBP decrease in the age group of Study IV, only awake DBP showed a natural trend around the retirement transition (Franklin, 2006; Franklin et al., 1997). This underlines the possible role of retirement transition in ABP. As the trend of awake and asleep SBP after the retirement transition resembled the trend before it, the participants possibly had other than work-related stressors after the transition, which in turn affected ABP.

The supplementary analysis in Study IV showed that asleep SBP and DBP increased more, and that consequently, SBP and DBP dipping decreased more among shift workers than among regular day workers during the retirement transition. As the asleep SBP and DBP values and the DBP dipping values were at a preferable level even after the retirement transition, some of the shift workers manifested SBP nondipping after the transition. As discussed earlier, this is associated with an increased risk of total mortality and cardiovascular mortality (Yang et al., 2019). More importantly, as a 10% decrease in SBP dipping has shown to increase the risk of stroke, cardiovascular outcomes, and cardiovascular mortality by 8–12% (Yang et al., 2019), a 4.8% decrease in SBP dipping must be taken into account among shift workers during their retirement transition. Moreover, the shift workers in Study I manifested higher awake SBP than the regular day workers. The shift workers in Study IV manifested higher awake BP than the regular day workers, but the differences between these two groups diminished after the retirement transition. Consequently, the stress induced by shift work affected awake BP but after quitting shift work, the workers were at a greater risk of asleep BP augmentation. The increasing asleep BP after the retirement transition could also be attributed to the different post-retirement lifestyles of shift workers and regular day workers. These results were mainly applicable to day-shift workers, as night shift workers were rare in Studies I and IV. The increased asleep SBP in the main analysis could result from the BP changes among the shift workers.

In Study IV, the changes in ABP during the retirement transition did not differ by job strain status or job demand status. In contrast, in Study I, the participants with low job demands had higher SBP and DBP dipping values than the participants with high job demands. Thus, job demands seemed to affect the ABP of aging workers, and the effect did not seem to decrease when they retired. It is possible that the workers with high job demands or high job strain had high demands or highly strenuous lifestyles during retirement and this may have affected their ABP. Finally, in Study IV, the ABP values did not differ according to sex or occupational status during the retirement transition. This finding was the opposite to the finding of a previous study that found an association between retirement transition and office BP, especially among men and urban dwellers (Xue et al., 2017). However, in that study, the follow-up was over 10 years instead of the two-year follow-up in Study IV, and thus the changes in BP resulting from the retirement transition were possibly more obvious during the longer follow-up. Moreover, Xue et al. adjusted for more covariates, including information on the participants' lifestyles, antihypertensive medication, spouse, income, and education, than Study IV. Men (Gilbert-Ouimet et al., 2014) and workers with low occupational status (Brown et al., 2006; Landsbergis et al., 2003b) have earlier been found to be more vulnerable to the work-related psychosocial stressors' effects on ABP than women and workers with high occupational status. Consequently, further research on the association between sex, work-related psychosocial stressors and retirement transition and on the association between occupational status, work-related psychosocial stressors and the retirement transition is required.

The exclusion of participants who were on antihypertensive medication reduced the differences between the awake DBP values measured after the retirement transition in comparison to the decreasing trend observed in the total study sample. Thus, although work-related factors seemed to have a greater effect on the BP values of those taking antihypertensive medication in Study I, the retirement transition seemed to have quite a similar effect on ABP, regardless of whether or not the participants were on antihypertensive medication.

Study IV had both strengths and limitations. The annually repeated ABP measurements were a major strength, although follow-up was only two to four years. Even though the percentage of shift workers was 24% in Study IV, the number of night-time workers remained small, which prevented the study of the effects of night work on ABP. Finally, adjustment for stressors not related to work could have provided further information on the impact of work-related psychosocial stressors on the ABP of aging workers.

6.5 Methodological considerations

The strengths of this PhD study include the use of longitudinal data in Studies III and IV, which enabled the examination of the prospective associations between work-related psychosocial stressors and home BP, and between retirement transition and ABP. The study populations consisted of aging workers. In the FIREA study, the study participants were retiring public sector employees in various occupations and workplaces. Thus, the results were more generalizable to the equally aged, working Finnish population than the results of previously published studies whose participants have been from only one workplace or occupation. However, the included FIREA study participants manifested somewhat healthier lifestyles and reported less job strain and hypertension than the FIREA Survey participants, and this limits the interpretation of the results. The DILGOM study participants were randomly selected, working individuals aged over 55 from Southwest Finland, and the Health 2000 study participants were randomly selected, 41–64-year-old working individuals from mainland Finland. The included DILGOM study participants did not differ from the survey participants and the included Health 2000 study participants did not differ from the health examination participants in terms of the variables tested. None of the studies excluded the participants on the basis of their medical or disease history, which enabled the sensitivity analyses including only the participants who were not on antihypertensive medication in Study I and Study IV, for example.

This study was based on study samples for which comprehensive information on socioeconomic status, lifestyles and health issues was available, which enabled the use of relevant covariates. In addition, although the majority of the FIREA study participants were women in Studies I, II and IV, both sexes were included in all the studies. The analyses in Studies III and IV showed no sex-based differences in home BP, ABP or BP dipping.

The work-related psychosocial stressors were assessed by the widely used JCQ (Fransson et al., 2012). Additionally, the methods used to measure large arterial health indicators were generally accepted and commonly used. The use of ambulatory and home BP values is recommended for confirming hypertension diagnoses (Stergiou et al., 2021). In addition, carotid-femoral PWV is still regarded the gold standard for noninvasive measurement of PWV (Laurent et al., 2006; Mancia et al., 2023; Van Bortel et al., 2012), although novel methods of measurement are under development (Milan et al., 2019).

Despite the advantages related to the study samples and methods, some limitations must also be addressed. First, as in all studies, the participants were working people with a mean age above 50, they were a somewhat select group of the general population. Consequently, the hypertension rates in all the study populations remained below those observed in the general population, reflecting better cardiovascular health (Koponen et al., 2018). Second, as the study samples were small in Studies I, II and IV, the CIs were wide, especially in the small subgroups. Third, as awake hours were not separated from working hours and home hours in the ABP measurements, BP during working hours and leisure time was not studied separately. As in earlier studies, work-related psychosocial stressors seemed to affect ABP not only during working hours but also during leisure time, and in the future it would be interesting to examine whether this also applies to aging workers.

Although it is known that salt consumption may affect BP levels (Robinson et al., 2019), it was not possible to control for this in the analysis, as the information was not available. Moreover, in Study IV, no information was available on the potential private life stressors affecting BP after the retirement transition. Finally, the causal association between work-related factors and ABP, and between life stressors and large arterial stiffness could not be assessed in cross-sectional Studies I and II, warranting future longitudinal studies.

6.6 Ethical considerations

This thesis was based on existing data gathered in three cohort studies: the FIREA study, the DILGOM study and the Health 2000 study, all of which have also provided data for numerous other articles. It can be considered ethical to utilize existing data when feasible rather than using resources for new data collection if not needed. As mentioned in the Methods, all studies were approved by the local Ethical committees as appropriate. The participants had provided written informed consent to participate and were allowed to withdraw from the studies whenever. At least in the Health 2000 Study, the participants were asked about their study experiences afterwards. The participants got feedback from the measurements made. Anonymity was guaranteed as the information on the participants was coded and no identifiable information on the participants was used in the analyses. The funders of the studies were mentioned in the articles. The funders did not affect the conduct of the studies or the reporting of the results.

6.7 Clinical relevance

The results of this PhD study suggest that worktime mode and job demands are associated with ABP. Although the awake SBP of shift workers was 4 mmHg higher than that of regular day workers in Study I, the shift workers were not necessarily at a greater risk of cardiovascular diseases than regular day workers (Narita et al., 2023). However, the risk of cardiovascular death is higher among shift workers than among regular day workers (Staplin et al., 2023), although the increased awake BP among shift workers may have been compensated by their greater BP dipping. In addition to worktime mode, we observed that individuals with high job demands were at a greater risk of being nondippers. Thus, according to Study I, the work-related factors of worktime mode and job demand status should be taken into account in aging workers' occupational health care when cardiovascular disease risk and the need for ABP measurement is being assessed.

In Study IV of this thesis, awake SBP stabilized during the retirement transition, although before and after the transition it decreased. Asleep SBP even increased during the transition in contrast to before and after it, when it remained stable. Although no similar changes were found in DBP, the retirement transition seemed to affect the systolic ABP values more than the diastolic ABP values. Asleep BP increased and BP dipping decreased more during the retirement transition among the shift workers than the regular day workers. Cardiovascular disease risk assessments of aging workers should focus on measuring the ABP of shift workers, who showed unfavorable BP changes during the retirement transition.

Although the PWV values of all the groups by life stressor status were generally normal at under 10 m/s (Mancia et al., 2023; Reference Values for Arterial Stiffness'

Collaboration, 2010) in Study II, the PVW of the participants with recent illness or death in their families or financial difficulties was ~0.5–1.0 m/s greater than that of their counterparts. As even a 1 m/s increase in PWV increases the risk of cardiovascular events by 17% (Zhong et al., 2018), this finding suggests that large arterial stiffness could explain some of the previously observed increased risks of cardiovascular disease related to life stressors (Carey et al., 2014; Graff et al., 2016; Khaing et al., 2017; Li et al., 2002; Minhas et al., 2023; Mostofsky et al., 2012; Wei et al., 2023).

In Study III of this thesis, the decrease in home BP between weekdays and weekend days was greater among those with high job strain and high job demands than among their counterparts. The results showed that the differences between the participants' home BP were mostly in the morning values and not the evening values. The differences between the groups' SBP and DBP changes from weekdays to weekend days in terms of job strain, and between the groups' SBP changes in terms of job demands ranged from 1.2 to 1.5 mmHg. As psychological stress is associated with increased morning surge (Kario, 2010), it could be speculated that the participants with high job strain or high job demands may be at a higher cardiovascular risk caused by increased morning surge. However, the difference in morning BP values associated with increased cardiovascular risk has been greater in earlier studies than those found in Study III (Kario, 2010). These findings should also be kept in mind when assessing the home BP of a patient, as work-related factors could have an impact on both day-to-day BP variation and BP level. Furthermore, as home BP seemed to decrease during the weekend, it may be worth testing whether different work-related stress interventions could reduce the level of home BP during the working week to the weekend level.

7 Conclusions

The overall aim of this thesis was to examine how life stressors are related to the cardiovascular health of aging workers. Its main findings were:

1) Shift workers manifested higher awake SBP values but also more preferable dipping profiles than those of regular day workers. Individuals with high job demands manifested lower BP dipping values than their counterparts. The changes in ABP induced by work-related factors were not visible as only aging workers who were not on antihypertensive medication were studied.
2) Individuals with recent serious life events or financial difficulties had higher large arterial stiffness than their counterparts. The accumulation of stressors seemed to be associated with numerically greater large arterial stiffness.
3) Individuals with high job strain or high job demands exhibited greater differences between BP on weekdays and weekend days than individuals with low job strain or low job demands. These results were mainly based on morning values, suggesting that work-related psychosocial factors are linked to the morning BP surge.
4) The retirement transition is associated with unfavorable changes in awake and asleep SBP compared to the periods before and after retirement transition. This finding was observed especially among shift workers. ABP is superior to office BP in capturing retirement-related changes in BP. Consequently, ABP should be considered a preferable BP measurement method for aging workers undergoing the transition to retirement.

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