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Personality traits as risk factors for stroke and coronary heart disease mortality: pooled analysis of three cohort studies

Markus Jokela · Laura Pulkki-Råback · Marko Elovainio · Mika Kivimäki

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Abstract We examined whether personality traits are differently associated with coronary heart disease and stroke mortality. Participants were pooled from three prospective cohort studies (Health and Retirement Study, Wisconsin Longitudinal Study graduate and sibling samples; n = 24,543 men and women, mean age 61.4 years, mortality follow-up between 3 and 15 years). There were 423 coronary heart disease deaths and 88 stroke deaths during 212,542 person-years at risk. Higher extraversion was associated with an increased risk of stroke (hazard ratio per each standard deviation increase in personality trait HR = 1.41, 95 % CI 1.10–1.80) but not with coronary heart disease mortality (HR = 0.93, 0.83–1.05). High neuroticism, in turn, was more strongly related to the risk of coronary heart disease (HR = 1.16, 1.04–1.29) than stroke deaths (HR = 0.95, 0.78–1.17). High conscientiousness was associated with lower mortality risk from both coronary heart disease (HR = 0.74, 0.67–0.81) and stroke (HR = 0.78, 0.63–0.97). Cardiovascular risk associated with personality traits appears to vary between main cardiac and cerebral disease endpoints.

Keywords Personality · Stroke · Coronary heart disease · Meta-analysis

Introduction

Personality represents the constellation of people's different behavioral, emotional, and cognitive styles. Specific personality traits have been suggested to affect the risk of physical illnesses and behavior-related health risk factors (Deary et al., 2010). Cardiovascular diseases have received perhaps the most attention in this context (Booth-Kewley & Friedman, 1987). The most consistent associations with cardiovascular outcomes have been found for higher-order personality traits of high neuroticism (or high negative affectivity; Kubzansky & Kawachi, 2000; McCarron et al., 2003), low agreeableness (or high hostility; Steptoe & Chida, 2009), and low conscientiousness (Martin et al., 2007; Terracciano et al., 2008). Thus, negative emotional states, interpersonal antagonism, and lack of self-discipline appear to be the most central personality components of cardiac risk and mortality.

Personality may influence health via multiple pathways but the details of these pathways remain poorly understood (Deary et al., 2010). Some personality traits, conscientiousness in particular, may improve health because individuals with high conscientiousness are more likely to adopt optimal health behaviors (Bogg & Roberts, 2004; Lodi-Smith et al., 2010). Other personality traits, such as extraversion, neuroticism and agreeableness, may influence people's emotional and social life, including sensitivity to

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M. Jokela (✉) · L. Pulkki-Råback
Institute of Behavioural Sciences, University of Helsinki, Siltavuorenpenger 1A, P.O. Box 9, 00014 Helsinki, Finland
e-mail: markus.jokela@helsinki.fi

M. Jokela
Department of Psychology, University of Cambridge, Cambridge, UK

M. Elovainio
National Institute of Health and Welfare, Helsinki, Finland

M. Kivimäki
Research Department of Epidemiology and Public Health, University College London, London, UK

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negative experiences (Watson & Clark, 1992) lack of social support (Connor-Smith & Flachsbart, 2007) and poorer abilities in adapting to difficult and changing life circumstances (Watson & Hubbard, 1996). The resulting psychosocial stress may then lead to elevated blood pressure, atherosclerosis, and other physiological risk factors (Steptoe & Kivimäki, 2012; Steptoe & Kivimäki, 2013), thereby increasing the risk of cardiovascular mortality (Kivimäki et al., 2012). Other personality-related pathways are also possible (Jonassaint et al., 2007; Smith & MacKenzie, 2006).

Cardiovascular disease is a systemic disease with multiple endpoints at various sites of the arterial tree (Perk et al., 2012). As causes of death, coronary heart disease is the most common manifestation of vascular diseases, followed by stroke (Kung et al., 2008). The metabolic risk factors for coronary heart disease and stroke are only partly overlapping, and the two diseases differ in underlying pathological processes of atherosclerosis, acute thrombosis, and vessel wall integrity (Puddu et al., 1995; Goldstein et al., 2011; Wilhelmsen et al., 2005). However, there is only limited data on whether the personality associations are different for coronary heart disease and stroke, as stroke has not been studied as extensively as coronary heart disease. In a large Japanese cohort (Nakaya et al., 2005), extraversion, neuroticism and psychoticism were not associated with ischemic heart disease or stroke mortality. In the British Health and Lifestyle Survey, higher neuroticism was associated with higher risk of coronary heart disease mortality but not with stroke mortality (Shipley et al., 2007) while extraversion was not associated with either coronary heart disease or stroke mortality.

The present study examined whether personality traits of the Five Factor Model (John et al., 2008) are differently associated with coronary heart disease and stroke mortality, and whether these associations are accounted for by cardiovascular risk factors, including smoking, obesity, physical inactivity, hypertension and diabetes. Data were pooled from 3 prospective cohort studies, which provided a sample size of almost 25,000 participants, and the results were pooled using individual-participant meta-analysis.

Methods and Materials

Participants

We searched the data collections of the Inter-University Consortium for Political and Social Research (http://www.icpsr.umich.edu/icpsrweb/ICPSR/) to identify eligible large-scale cohort studies for which data were publicly available. The studies had to include baseline personality assessment using a standardized inventory of the full Five Factor Model (John et al., 2008) and have a follow-up for cardiac and cerebrovascular causes of death. We obtained individual-level data for 3 cohorts: the Health and Retirement Study (n = 13,900), and the Wisconsin Longitudinal Study graduate (n = 6,674) and the Wisconsin Longitudinal Study sibling (n = 3,969) samples.

The Health and Retirement Study is a nationally representative longitudinal study of more than 30,000 individuals representing the U.S. population older than 50 years (Juster & Suzman, 1995) Telephone or in-person interviews are conducted every 2 years. The current cohort consists of the original cohort recruited in 1992 from Americans born in the years 1931 through 1941, the Study of Assets and Health Dynamics Among the Oldest Old cohort, a subsample of individuals born between 1924 and 1930 (Children of the Depression Age), and a subsample consisting of people born between 1942 and 1947 (War Baby cohort). Personality questionnaire was administered to half of the sample in 2006 and to the other half in 2008. Thus, the study baseline was 2006 for half of the sample and 2008 for the other half of the sample. Baseline data on other covariates were derived from the year of personality assessment, and mortality follow-up extended up to year 2010.

The Wisconsin Longitudinal Study has followed a random sample of 10317 participants (5,326 women, 4,991 men) who were born between 1937 and 1940 and who graduated from Wisconsin high schools in 1957 (Wollmering, 2007). After baseline data collection in 1957, survey data have been collected from the participants or their parents in 1964, 1975, 1992/1993, and 2003/2005. The present study used data from the 1993 follow-up. In addition to the main sample of the 1957 high school graduates, the study has also collected data on a selected sibling of a sample of the graduates (Hauser et al., 1982). The data collection in adulthood has been very similar but not identical for the siblings and the graduates. For the present purposes, the sibling and graduate samples were analyzed separately. Mortality follow-up extended up to year 2009. Table 1 provides the characteristics of the samples. All the studies were approved by the relevant local ethics committees.

Measures

The Five Factor Model of personality used in the present study is widely recognized as the most comprehensive model of the major dimensions of personality (John et al., 2008), and it includes *conscientiousness* (high self-control, tendency to plan ahead, persistence and task-orientation), *neuroticism* (sensitivity to negative emotions, propensity to symptoms of depression and anxiety), *extraversion* (tendency to seek stimulation in the company of others, dis-

Table 1 Descriptive statistics of the samples

	HRS	WLSG	WLSS
Total number of participants	13,900	6,674	3,969
Sex (% female)	59.2 (8,231)	53.8 (3,591)	53.5 (2,122)
Age at baseline (years)	67.3 (10.4)	54.1 (0.5)	53.1 (7.4)
Race/ethnicity (% White)	78.0 (10,841)	100.0 (6,674)	100.0 (3,969)
Diabetes	20.4 (2,840)	3.9 (261)	5.0 (196)
Obesity	30.9 (4,236)	18.2 (1,188)	17.9 (690)
Hypertension	59.6 (8,285)	21.2 (1,415)	26.3 (1,026)
Current smoker	13.2 (1,826)	17.7 (1,164)	17.2 (670)
Physical inactivity	35.2 (4,893)	19.0 (1,253)	15.4 (605)
CHD deaths	2.2 (303)	1.1 (73)	1.2 (47)
Stroke deaths	0.5 (67)	0.2 (13)	0.2 (8)

Values are percentages (and numbers) of participants, except for age (mean and standard deviations in years)

HRS Health and Retirement Study, *WLSG* Wisconsin Longitudinal Study, Graduate sample, *WLSS* Wisconsin Longitudinal Study, Sibling sample

position to experience positive emotions easily and more frequently), *openness to experience* (appreciation for variety of experience in different domains of life, open-mindedness), and *agreeableness* (tendency to be cooperative rather than competitive and antagonistic towards others, showing empathy). In Health and Retirement Study, personality was assessed with a 21-item questionnaire adapted from the Midlife in the United States study (Lachman & Weaver, 1997) with 5 items for extroversion (Cronbach's $\alpha = 0.74$), 4 items for emotional stability (0.63), 5 items for agreeableness (0.78), 5 items for conscientiousness (0.63), and 7 items for openness to experience (0.79), rated on a 4-point rating scale. In the Wisconsin cohorts, personality was assessed with a 29-item Big Five Inventory (John et al., 2008). Participants were asked whether they agreed or disagreed that certain personality descriptions fitted themselves using a 6-point rating scale. The Cronbach alpha estimates were 0.76 for extraversion in graduates/0.65 in siblings for extraversion, 0.78/0.63 for neuroticism, 0.69/0.70 for agreeableness, 0.64/0.70 for conscientiousness, and 0.61/0.70 for openness to experience.

Mortality data were derived from the National Death Index and/or via household proxy reports of a non-respondent's vital status, recorded with month's accuracy. Cause-specific mortality data were available in the Wisconsin cohorts based on ICD codes (cohort heart disease defined as ICD-9 codes 410-414 and 429.2 or ICD-10 coded I20-I25; stroke defined as ICD-9 codes 430-438, or ICD-10 codes I60-I69). In Health and Retirement Study, information on cause of death has not been released with specific ICD codes but as collapsed categories based on the ICD codes. Coronary heart disease was defined as "heart attack (coronary) or failure; arteriosclerosis; heart aneurysms; heart deformities/congenital heart deformities; angina; bad heart; congestive heart disease; cardiomyopathy; atrial fibrillation; myocardial infarction; multiple infarction; myocardinitus, endocarditis; myocardial ischemia; heart murmurs; heart valve blockage; heart valve prolapse; heart valve replacement; arterial blockage; hardening of arteries; heart bypass surgery; mitral valve prolapse; myocardial ischemia; rheumatic heart disease" as the underlying cause of death, and stroke mortality was defined as "stroke; cerebral hemorrhage or accident; hemotoma (if related to brain); transient ischemic attack" as the underlying cause of death.

To examine whether the associations between personality and cardiovascular risk were explained by common risk factors for cardiovascular diseases, we adjusted the models additionally for important cardiovascular risk factors. Covariate data in both cohorts included obesity calculated from self-reported height and weight ($0 =$ non-obese, body mass index < 30; $1 =$ obese, body mass index ≥ 30), smoking (coded as $0 =$ non- or ex-smoker, $1 =$ current smoker), leisure-time physical inactivity (coded as $0 =$ moderately or very active, $1 =$ inactive), and self-reported diabetes and hypertension ($0 =$ no, $1 =$ yes for both diseases).

Statistical Analysis

The associations between personality traits and mortality from coronary heart disease and stroke during the follow-up period were assessed using Cox's proportional hazards model. Time was coded in months. The five personality traits were standardized into z-scores within the sample (mean $= 0$, standard deviation $= 1$) and were simultaneously included in the models to estimate their indepen-

dent effects. To examine whether these independent associations were similar to individual associations of each personality trait, we also fitted the proportional hazard models separately for each trait without adjusting for the other traits. All models were further adjusted for sex, age at baseline, race/ethnicity (0 = white, 1 = non-white). The proportional hazards models were first fitted separately in the 3 cohorts, and the estimates from the individual cohorts were then pooled together using random-effect meta-analysis procedure of STATA 12.1 statistical software (Texas, USA).

Results

Mean follow-up for mortality varied between 3.1 and 15.2 years depending on the study (mean = 8.0 years). During 212,542 person-years at risk, 423 coronary heart disease and 88 stroke deaths occurred. In multivariable models including all the personality traits together, higher conscientiousness was related to lower risk of death from coronary heart disease (hazard ratio per 1 standard deviation increase in personality trait HR = 0.74, 95 % CI 0.67–0.81; Fig. 1) and stroke (HR = 0.78, CI 0.63–0.97; Fig. 2). Higher extraversion was associated with higher risk of stroke (HR = 1.41, CI 1.10–1.80) but not with coronary heart disease mortality (HR = 0.93, CI 0.83–1.05), and these two associations were statistically significantly different from each other ($p = 0.003$ for heterogeneity in effect size). In addition, higher neuroticism was associated with higher risk of coronary heart disease (HR = 1.16, CI 1.04–1.29) but not with stroke mortality (HR = 0.95, CI 0.78–1.17). The difference between these two associations was marginally significant ($p = 0.10$ for heterogeneity in effect size). Agreeableness and openness to experience were not associated with coronary heart disease or stroke mortality. Effect size heterogeneity estimates were modest, with no significant I^2 indices for any of the personality traits (Figs. 1, 2).

Adjustments for cardiovascular risk factors had mostly modest influence on the associations described above (Table 2). After additionally adjusted for smoking, obesity, diabetes, hypertension, and physical inactivity at baseline, the association of conscientiousness attenuated by 16 % for coronary heart disease mortality (from HR = 0.73 to HR = 0.78) and by 18 % for stroke mortality (from 0.79 to 0.82). The corresponding attenuation for neuroticism and coronary heart disease was 26 % (from 1.16 to 1.12), while the association between extraversion and stroke was strengthened by 21 % (from 1.43 to 1.52). The details of these analyses are reported in Figures 1 and 2 of the electronic supplementary material.

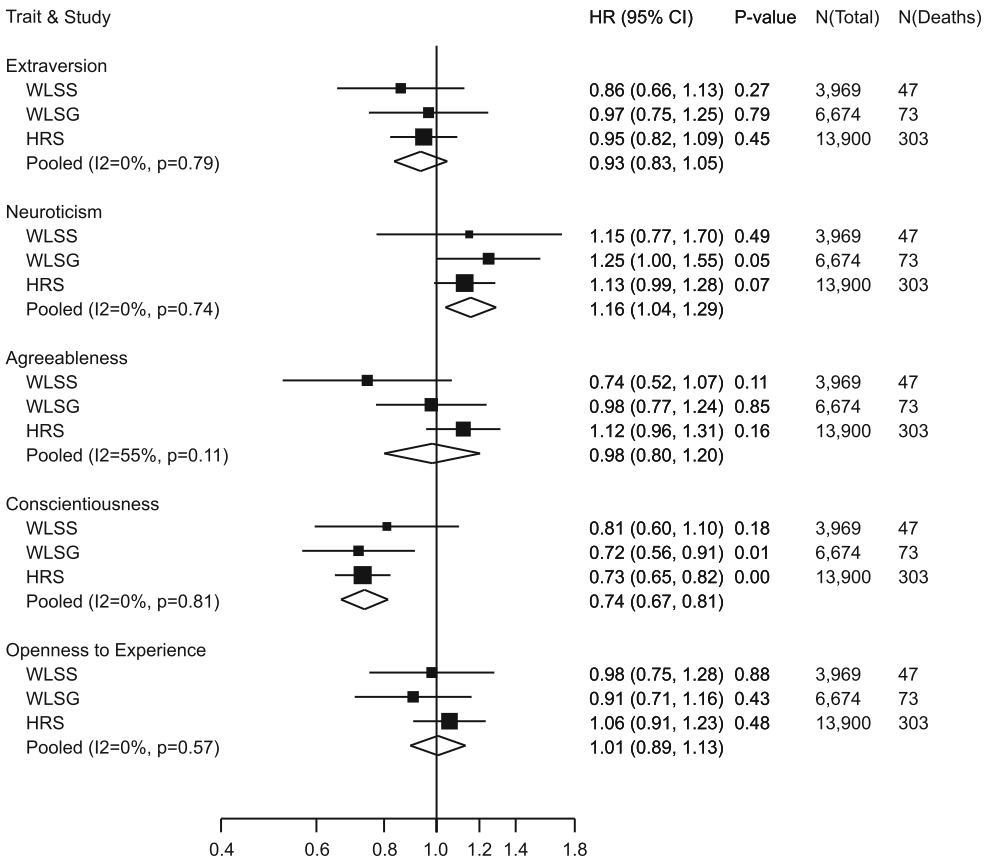

Fig. 1 Risk of coronary heart disease mortality associated with 1 standard-deviation difference in personality trait scores. Values of I^2 indicate the degree of heterogeneity in the association across studies

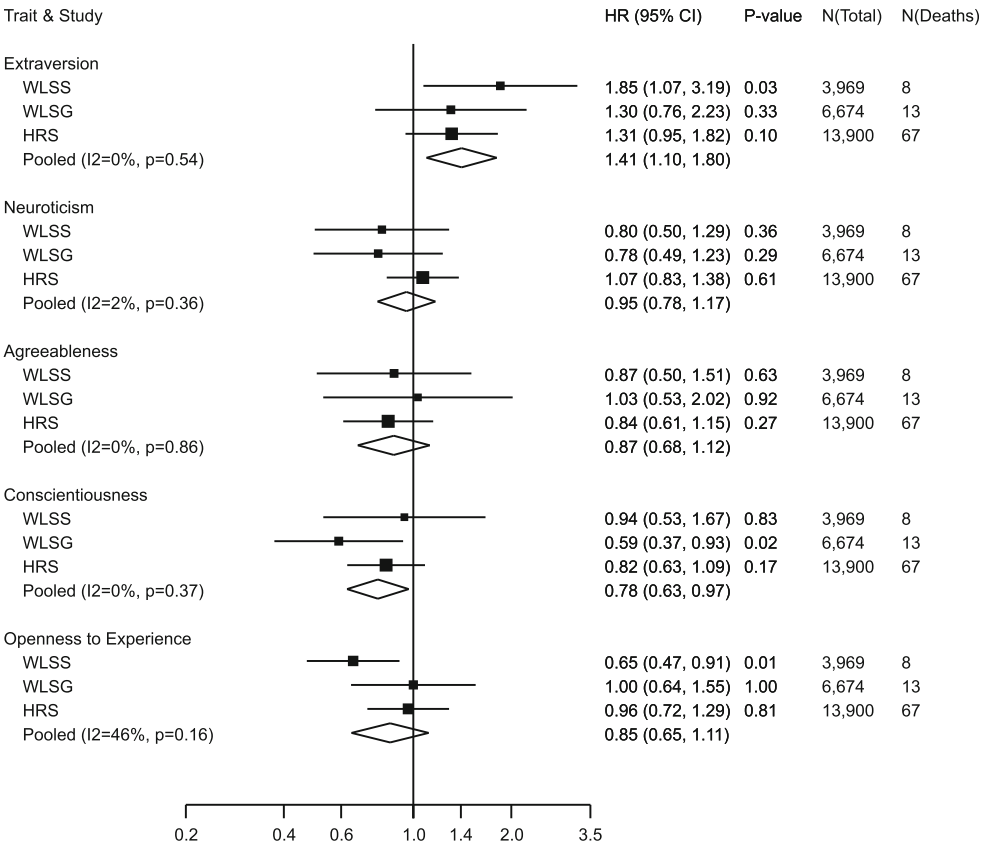

Fig. 2 Risk of stroke mortality associated with 1 standard-deviation difference in personality trait scores. Values of I^2 indicate the degree of heterogeneity in the association across studies

Table 2 Associations of personality traits with coronary heart disease and stroke mortality, adjusted for baseline covariates

	Outcome: CHD mortality		Outcome: Stroke mortality	
	Conscientiousness	Neuroticism	Conscientiousness	Extraversion
Adjusted for				
Sex, age, race/ethnicity	0.73 (0.66, 0.81)	1.16 (1.04, 1.29)	0.79 (0.61, 1.02)	1.43 (1.11, 1.84)
+ Smoking	0.74 (0.67, 0.82)	1.15 (1.03, 1.28)	0.79 (0.61, 1.04)	1.44 (1.11, 1.86)
+ Hypertension	0.74 (0.67, 0.82)	1.13 (1.01, 1.26)	0.79 (0.62, 1.03)	1.43 (1.11, 1.84)
+ Diabetes	0.75 (0.68, 0.83)	1.15 (1.03, 1.29)	0.80 (0.62, 1.02)	1.44 (1.11, 1.87)
+ Obesity	0.74 (0.67, 0.82)	1.16 (1.04, 1.29)	0.80 (0.63, 1.00)	1.43 (1.11, 1.84)
+ Physical inactivity	0.75 (0.68, 0.83)	1.14 (1.02, 1.27)	0.79 (0.61, 1.02)	1.50 (1.16, 1.94)
+ All above	0.78 (0.70, 0.86)	1.12 (1.00, 1.24)	0.82 (0.65, 1.04)	1.52 (1.16, 1.98)

N = 23,841 participants with 410 CHD deaths and 86 stroke deaths due to missing data in covariates. Values are hazard ratios (and 95 % confidence intervals)

CHD coronary heart disease

When the personality traits were examined in separate models, adjusted for age, sex, and race/ethnicity, higher risk of coronary heart disease mortality was associated with lower extraversion (HR = 0.85, CI 0.78, 0.94), higher neuroticism (HR = 1.27, CI 1.13, 1.43), lower agreeableness (HR = 0.81, CI 0.67, 0.99), lower conscientiousness (HR = 0.73, CI 0.67, 0.80), and lower openness to experience (HR = 0.86, CI 0.78, 0.96). Stroke mortality was marginally predicted by lower conscientiousness (HR = 0.83, CI 0.69, 1.00, $p = 0.05$) but not by other traits. The details of these analyses are reported in Figures 3 and 4 of the electronic supplementary material.

Discussion

Our findings suggest that high conscientiousness is associated with lower risk of coronary heart disease and stroke mortality, with no evidence of heterogeneity in associations with these two endpoints. Individuals with high conscien-

tiousness (1 standard deviation above the mean) had approximately 40–50 % lower cardiovascluar-related mortality risk compared to individuals with low conscientiousness (1 standard deviation below the mean). By contrast, high neuroticism was a risk factor for coronary heart disease mortality but not for stroke mortality, and high extraversion was a risk factor for elevated stroke mortality but not coronary heart disease mortality. This suggests that cardiovascular risk associated with personality differences may be different for main cardiac and cerebral disease endpoints.

The methodological strengths of the present study include a pooled sample of 3 cohorts and almost 25,000 participants, assessment of all the five main dimensions of personality, analysis of both stroke and cardiovascular mortality as outcomes, and inclusion of many cardiovascular risk factors as covariates. The main limitation of the study was the use of relatively brief personality inventories that did not include subscales of the higher-order traits. Some of the health associations of personality may be specific to lower-order subscales and therefore not accurately captured by scales measuring only the higher-order traits (Weiss & Costa, 2005; Jonassaint et al., 2007; Terracciano et al., 2009). Another limitation was the lack of clinical measurements of underlying physiological mechanisms, which precluded the analysis of trait-specific associations with pathophysiological processes related to coronary heart disease and stroke.

Conscientiousness has been associated with a broad range of optimal health behaviors and outcomes (Bogg & Roberts, 2004; Jokela et al., 2013a; Martin et al., 2007). Conscientiousness appears to be the main personality trait predicting all-cause mortality (Jokela et al., 2013a) diabetes (Jokela et al., in press) and obesity (Jokela et al., 2013b) among other health outcomes. Highly conscientious individuals are able to make long-term plans and to stick to them (Martin et al., 2007), and conscientious individuals may also be more likely to search and adhere to health-relevant information (Hill & Roberts, 2011). These cognitive-behavioral styles and health behaviors are likely to contribute to the lower cardiovascular mortality risk associated with conscientiousness. However, health behaviors have been found to explain only part of the associations between conscientiousness and better health (Jokela et al., 2013a; Deary et al., 2010), which was also the case in the present study, so other mechanisms are likely to be involved. One possibility is that conscientiousness and cardiovascular health have common developmental origins, such as shared family influences, early exposure to adverse environments, or common genetic factors. If health trajectories and personality development are influenced by partly the same environmental or genetic factors, the observed associations between personality traits and health outcomes may not reflect causal effects but are explained by confounding. This hypothesis has been explored in relation to intelligence (Jokela et al., 2011) and depressive symptoms (McCaffrey et al., 2006) but not with personality. Sibling comparisons and twin studies with personality data would be informative in testing whether shared developmental origins account for any of the associations between personality and health.

Our findings regarding neuroticism are in agreement with previous evidence on the elevated cardiovascular risk associated with high neuroticism/negative affect (Shipley et al., 2007; Kubzansky & Kawachi, 2000), although not all studies have observed this association (Almada et al., 1991). Negative emotions may be linked to coronary heart disease via physiological pathways such as dysregulation of the autonomic nervous system and activation of the hypothalamic-pituitary-adrenocortical axis (Manuck et al., 1995). Over time, recurring activation of these systems may enhance development of cardiovascular risk factors such as the progression of atherosclerosis, metabolic syndrome, decreased heart rate variability, and inflammatory markers, all of which are known to contribute to cardiovascular disease mortality (Brook & Julius, 2000; Steptoe et al., 2007; Rothwell et al., 2010). In contrast to some previous findings (Steptoe & Chida, 2009), the present results did not provide support for the role of low agreeableness (i.e., interpersonal hostility and antagonism) in the etiology of cardiovascular diseases.

While several studies have examined associations between personality traits and heart diseases, we are aware of only two prospective studies examining personality and stroke risk. In a large Japanese cohort (Nakaya et al., 2005), personality was assessed with three traits based on the Eysenck Personality Questionnaire, and no association with stroke risk or ischemic heart disease was observed for highest versus lowest tertiles in extraversion, neuroticism, or psychoticism. In the British Health and Lifestyle Survey, higher neuroticism was associated with higher risk of coronary heart disease mortality but not with stroke mortality (Shipley et al., 2007), which is in agreement with our current results concerning the differential associations of neuroticism with coronary heart disease and stroke.

Higher extraversion was consistently associated with elevated stroke risk in the 3 cohorts. Previous studies have suggested that extraversion is unrelated to (Shipley et al., 2007; Nakaya et al., 2005) or protective agaist cardiovascular risk (Chida & Steptoe, 2008; Boehm & Kubzansky, 2012). On possible explanation for the association between high extraversion and stroke risk observed here is that high extraversion exposes people to traumatic head injuries over the life course (Schwebel & Plumert, 1999; Clarke & Robertson, 2005; Vollrath et al., 2003; Jokela et al., 2009), and the head injuries increase the risk of stroke mortality

later in life (Chen et al., 2011; Burke et al., 2013). Furthermore, extraversion is correlated with social dominance (Traupman et al., 2009; Depue & Collins, 1999), and social dominance has been associated with higher coronary heart disease and all-cause mortality (Siegman et al., 2000; Houston et al., 1997). The assertive aspects of extraversion that prompt individuals to seek and retain social dominance might therefore increase cardiovascular morbidity, possibly via the psychosocial stress associated with maintaining dominant social relations (Smith et al., 1989).

The differential personality correlates of main cardiac and cerebral disease endpoints suggest that unique pathological mechanisms may mediate the associations between personality and the cardiovascular system. Some risk factors, such as abnormalities of lipid levels, are known to be particularly strong risk factors for coronary heart disease (Baigent et al., 2005) whereas others, such as head trauma, are strong predictors of stroke (Chen et al., 2011). Our findings raise the hypothesis that neuroticism might contribute directly, or indirectly via health behaviours, to risk specific to coronary heart disease whereas extraversion is more likely to influence stroke-specific pathways, potentially including head-related injuries or adverse effects of social dominance. The multivariate analyses suggested that the personality associations were only partly accounted for by five major cardiovascular risk factors (smoking, obesity, physical inactivity, hypertension, and diabetes), but further research is needed to examine a wider range of physiological and behavioral mechanisms, including other coronary heart disease or stroke specific factors, such as blood pressure variability.

In sum, high conscientiousness appears to reduce cardiovascular disease risk in general whereas high neuroticism may be specifically associated with coronary heart disease risk and high extraversion with stroke risk. Further research is needed to confirm our findings and to examine in detail the pathophysiological mechanisms driving the personality-cardiovascular disease associations.

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Conflict of interest None of the authors have any competing interests. The study sponsors did not contribute to the study design and had no role in data collection, data analysis, data interpretation, or the writing of the report.

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