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Is Within-Individual Variation in Personality Traits Associated with Changes in Health Behaviours? Analysis of Seven Longitudinal Cohort Studies

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Abstract: Personality traits are related to health behaviours, but it is unknown whether changes in personality would lead to changes in health behaviours. We examined whether naturally occurring, within-individual variation in personality traits over time is associated with corresponding changes in smoking, physical activity, alcohol consumption, and body mass index. Data were from seven longitudinal cohort studies with a total sample of 56 786 participants with two or three repeated measurements of the Five Factor Model personality traits assessed over 4 to 19 years. Repeated measurements were used to tease apart between-individual and within-individual associations. In the within-individual analysis, all the personality traits were associated with physical activity, and extraversion was associated with risky alcohol consumption. There were no other within-individual associations. In the between-individual analysis, lower conscientiousness, emotional stability, agreeableness, and openness to experience, and higher extraversion, were associated with many risky health behaviours. Our findings suggest that health behaviours are related mostly to stable, between-individual differences in personality traits, but changes in adult personality may have only limited association with changes in health behaviours. © 2018 European Association of Personality Psychology

Key words: medical illness; development of personality; physical traits

Personality has been related to many important health outcomes, including all-cause mortality (Graham et al., 2017; Jokela et al., 2013), dementia (Low, Harrison, & Lackersteen, 2013), cardiovascular disease (Jokela, Pulkki-Råback, Elovainio, & Kivimäki, 2014), obesity Jokela et al., 2013), and type 2 diabetes (Jokela et al., 2014). Personality has also been associated with health behaviours, such as smoking (Hakulinen et al., 2015), physical inactivity (Sutin et al., 2016), and heavy alcohol consumption (Hakulinen et al., 2015), and with subclinical biomarkers of health, such as systemic inflammation (Luchetti, Barkley, Stephan, Terracciano, & Sutin, 2014) and lung function (Terracciano, Stephan, Luchetti, Gonzalez-Rothi, & Sutin, 2016). Of the personality traits included in the Five Factor Model, low conscientiousness has emerged as the most robust personality correlate of poor health, being associated with a wide range of diseases, risky health behaviours, and mortality from all causes and specific causes. High extraversion and lower emotional stability are also associated with poor health behaviours but less so with all-cause mortality or most chronic diseases (Jokela, 2018). Low agreeableness and low openness to experience have predicted some specific health outcomes, such as increased risk for Alzheimer's disease (Terracciano et al., 2014) and lower frequency of physical activity (Sutin et al., 2016).

Studies of personality could help to identify psychological characteristics that expose people to modifiable health risks and thus inform health preventions and interventions (Hampson, 2012; Turiano, Chapman, Gruenewald, & Mroczek, 2015). Under the assumption of causality, the associations between personality traits and health behaviours imply that changes in a person's personality traits will lead to corresponding changes in their health behaviours (English & Carstensen, 2014). For example, a person whose conscientiousness increases over time would be expected to become more physically activity and reduce smoking and alcohol consumption. If, on the other hand, the personality traits were mere risk markers for poor health behaviours, there would be no causal associations, and therefore, no co-occurring changes of personality and health behaviours would be expected (Kim, 2016; Turiano, Pitzer, et al., 2012).

To address the issue of causality, one would ideally carry out a randomized trial where personality traits were modified in the treatment group. Changes in health behaviours would then be compared with those in a control group over a sufficient follow-up time (Chapman, Hampson, & Clarkin, 2014; Conrod et al., 2013). Such an experiment might not be feasible because it would require an effective treatment protocol for a long-term personality change and a sufficiently long follow-up period to allow health behaviours to change. In

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the absence of such experiments, quasi-experimental study designs can be used to gather clues of causality. Any single quasi-experimental study design cannot provide a definitive answer to the question of causality, but converging evidence from different quasi-experimental studies can triangulate reasonable evidence for or against causal interpretations (Lawlor, Tilling, & Smith, 2017).

A longitudinal study with only one baseline measurement of personality does not provide robust evidence for causality because this study design is not effective in controlling for potential confounders that influence both personality and health behaviours. A better study design would include repeated measurements of both personality traits and health behaviours from the same participants to test whether naturally occurring variation in personality is accompanied by corresponding changes in health behaviours (Gunasekara, Richardson, Carter, & Blakely, 2014; Jokela, 2014, 2015). The within-individual analysis of repeated measurements is not affected by any of the person's characteristics that remain the same over time for, as the analysis only considers within-individual variations across measurement times. Family background, genetic dispositions, and adult educational level are some of the potential confounding factors that might explain associations between personality and health behaviours (e.g. Jokela, Batty, et al., 2013; Kim, 2016; Morton, Turiano, Mroczek, & Ferraro, 2018), but they cannot confound the within-individual associations insofar as they do not change over time for the same individual. Within-individual analysis is particularly useful in addressing potential confounding because one does not need to measure the confounders to adjust for them in the analysis.

In this multi-cohort study, we used repeated-measurement data to examine whether within-individual variation in personality traits is related to within-individual variation in health behaviours. We hypothesized that personality traits are causally related to health behaviours and thereby, the naturally occurring personality variation over time is associated with variation in health behaviours. The effect sizes of the within-individual associations are therefore expected to be similar to the between-individual effect sizes. To obtain robust evidence, we tested this hypothesis in seven longitudinal studies from the USA, the UK, Germany, Australia, and Japan with a total sample size of more than 56 000 participants. We had not preregistered any hypotheses.

MATERIALS AND METHODS

Participants were from seven independent studies with a total of eight cohorts, as one of the studies included two subsamples. The included studies were the Household, Income, and Labour Dynamics in Australia; the Health and Retirement Study; the Midlife in the United States (MIDUS); the Midlife in Japan (MIDJA) study; the German Socio-economic Panel Study; the Wisconsin Longitudinal Study with the graduate and sibling samples; and the UK Household Longitudinal Study (UKHLS), which originally began as the British Household Panel Survey in 1991 and was extended to UKHLS in 2009 with the repeated measurements derived from participants who participated both in the UKHLS and British Household Panel Survey. The descriptive statistics of the cohorts are reported in Table 1, and full description of the cohorts can be found in the Supporting Information. We cannot make the data openly available because we do not own the rights to the data sets, but all the data are openly available from the Inter-university Consortium for Political and Social Research (icpsr.umich.edu), the UK Data Service (ukdataservice.ac.uk), or the study websites as described in the Supporting Information, which also provides the variable names in the different data sets and templates for the statistical analyses used to produce the results.

The Supporting Information reports the details of the measures in each cohort study. Briefly, *personality* was assessed with different instruments of the Five Factor Model, including a 36-item Big Five Markers Scale (Household, Income, and Labour Dynamics in Australia), a 25-item Big Five scale developed in the MIDUS study (MIDUS, Health and Retirement Study, and MIDJA), a 29-item version of the Big Five Inventory (Wisconsin Longitudinal Study with the graduate and sibling samples), and a 15-item short Big Five Inventory (German Socio-economic Panel Study and UKHLS). *Smoking* was coded dichotomously (non-smoker versus current smoker) based on self-reports. For participants who were smokers, we also examined the number of cigarettes smoked per day (coded as a continuous variable). *Physical inactivity* was assessed with self-reported frequencies of moderate or vigorous leisure-time physical activity. Physical inactivity was coded as a dichotomous variable because different studies had different ways of measuring it, making it impossible to harmonize a continuous measure across cohorts. Alcohol consumption was assessed with three different indicators: *number of alcoholic drinks per week* (treated as a continuous variable), *heavy alcohol consumption* (21 or more drinks per week for men and 14 or more drinks for women per week), and *binge drinking* (having had five or more drinks in one occasion during the last month). *Body mass index* (BMI) was calculated as weight in kilograms divided by height in metres squared, based on self-reported height and weight. We also created a *sum of health risks* by summing together dichotomous indicators of physical inactivity, heavy alcohol consumption, smoking, and obesity (BMI > 30 kg/m^2). MIDJA and UKHLS were not included in the analysis of the sum score because these cohorts did not have data on all the health indicators.

Statistical analysis

The data were transformed into a multilevel data structure of person-observations in which each participant could contribute multiple person-observations to the data set. Random-intercept regression models with person as the level 2 clustering factor were fitted to take into account the non-independence of the repeated person-observations and individual differences in the averages of the outcome variables. The analysis is based on separating within-individual variation over time from the stable between-individual differences in average personality trait levels by examining only the within-individual variation around the person's own average

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Table 1. Descriptive statistics of the cohort studies included in the analysis of between-individual and within-individual associations

	HILDA	HRS	MIDJA	MIDUS	SOEP	UKHLS	WLSG	WLSS
Smoking status								
Non-smoker	20 571 (81.9)	19 176 (88.0)	980 (77.8)	8962 (85.2)	27 134 (73.6)	11 600 (78.1)	14 503 (87.7)	7904 (87.2)
Current smoker	4561 (18.1)	2604 (12.0)	280 (22.2)	1553 (14.8)	9719 (26.4)	3260 (21.9)	2030 (12.3)	1163 (12.8)
Physical inactivity								
Physically active	18 983 (73.6)	15 446 (64.5)	—	5516 (52.8)	23 211 (59.2)	—	12 545 (82.1)	6886 (82.2)
Physically inactive	6807 (26.4)	8502 (35.5)	—	4926 (47.2)	15 975 (40.8)	—	2739 (17.9)	1491 (17.8)
Alcohol consumption								
Abstainer	6703 (38.0)	11 082 (56.2)	453 (35.1)	3035 (30.3)	3508 (13.0)	—	1826 (14.7)	2111 (27.3)
Moderate consumption	9109 (51.6)	8164 (41.4)	737 (57.2)	6536 (65.2)	19 210 (71.0)	—	10 021 (80.5)	5337 (69.0)
Heavy consumption	1827 (10.4)	464 (2.4)	99 (7.7)	455 (4.5)	4353 (16.1)	—	596 (4.8)	289 (3.7)
Binge drinking								
No binge drinking	—	17 196 (87.3)	931 (72.5)	5579 (88.7)	—	—	6892 (83.8)	4749 (87.7)
Binge drinking	—	2498 (12.7)	354 (27.5)	713 (11.3)	—	—	1337 (16.2)	669 (12.3)
Sex								
Men	11 928 (46.0)	9591 (40.0)	614 (47.3)	4712 (44.8)	18 759 (47.6)	6674 (44.0)	7659 (45.6)	4286 (46.3)
Women	13 998 (54.0)	14 364 (60.0)	684 (52.7)	5805 (55.2)	20 631 (52.4)	8492 (56.0)	9155 (54.4)	4981 (53.7)
Body mass index*	26.9 (5.5)	28.4 (5.9)	—	27.5 (5.7)	26.2 (4.7)	27.9 (5.3)	27.7 (5.0)	27.7 (5.1)
Number of cigarettes*	11.9 (9.5)	14.5 (11.3)	27.1 (14.3)	25.7 (13.3)	—	3.1 (7.2)	21.9 (15.8)	21.0 (16.1)
Alcoholic drinks per week*	6.6 (10.7)	3.0 (6.7)	6.2 (9.6)	3.0 (6.2)	4.1 (7.4)	—	4.4 (6.4)	3.6 (6.0)
Age*	43.8 (16.8)	66.3 (9.5)	54.8 (13.5)	47.1 (12.1)	46.8 (16.7)	45.3 (16.4)	54.1 (0.5)	52.5 (6.9)
Sum of health risks*	0.76 (0.83)	0.80 (0.80)	—	0.91 (0.83)	0.99 (0.86)	—	0.57 (0.72)	0.57 (0.73)
Number of measurements								
Two	2427 (25.7)	6093 (60.8)	649 (100.0)	1564 (38.8)	5889 (39.0)	7583 (100.0)	2302 (36.1)	1518 (42.2)
Three	7024 (74.3)	3923 (39.2)	—	2463 (61.2)	9204 (61.0)	—	4070 (63.9)	2077 (57.8)
n (participants)†	9451	10 016	649	4027	15 093	7583	6372	3595
n (person-observations)‡	25 920	23 955	1292	10 517	39 381	14 991	16 789	9252

Note: Values are numbers of participants (and percentages) unless otherwise *note*d. HILDA, Household, Income, and Labour Dynamics in Australia; HRS, Health and Retirement Study; MIDJA, Midlife in Japan; MIDUS, Midlife in the United States; SOEP, German Socio-economic Panel Study; UKHLS, UK Household Longitudinal Study; WLSG, Wisconsin Longitudinal Study with the graduate sample; WLSS, Wisconsin Longitudinal Study with the sibling sample.
*Values are means (and standard deviations). †Values are numbers of participants.
‡Values are numbers of person-observations over all the follow-up times.

level of the trait. The regression equation then becomes: $y_{ij} = \alpha + \beta_{0i} + \beta_B(\bar{x}_{i.}) + \beta_W(x_{ij}-\bar{x}_{i.}) + \varepsilon_{ij}$ in which y_{ij} is the observed outcome variable for person i at measurement time j, α is the overall intercept, β_{0i} is the person-specific intercept, x_{ij} is the personality trait of person i assessed at measurement time j, $\bar{x}_{i.}$ is the within-person average of x_i across all measurement times, and ε_{ij} is the level 1 residual term. The coefficient β_B gives the between-individual association and β_W the within-individual association. The within-individual analysis requires variation in the outcome variable, so participants for whom the outcome does not vary over time do not contribute information of the estimation of within-individual coefficients. For example, participants who were non-smokers in all their measurement times would not contribute data to within-individual estimation, as their smoking status did not vary over time. They did contribute information for the estimation of between-individual associations. We report separately the numbers of participants who contributed to the within-individual associations in different outcome variables.

Personality traits were all standardized within each cohort using the baseline measurement time as the reference value [baseline personality trait mean = 0, standard deviation (*SD*) = 1]. The overall associations between personality and health behaviours were first assessed by including all participants in the analyses (up to 80 216 participants). In the comparison of between-individual versus within-individual associations, we only included participants who had data from at least two measurement times (excluding a total of 25 746 participants with only one measurement time) to estimate between-individual associations only among participants who could contribute to the within-individual analysis. Within-individual stability of personality and health behaviours across measurement times were estimated using intraclass correlations that quantify the proportion of the total variance in the variable explained by the average between-individual differences—the higher the intraclass correlation, the less within-individual variation.

Physical inactivity, smoking, heavy alcohol consumption, and binge drinking were analysed with logistic regression, with coefficients expressed as logit odds ratios per 1 *SD* difference in personality trait; BMI, number of alcoholic drinks per week, and number of cigarettes per day with linear regression, with coefficients expressed as outcome difference in standardized units (*SD* = 1) of the outcome per 2 *SD* difference in personality trait (we used 2 *SD* in order to avoid overly small coefficients); and the sum of health risks with negative binomial regression, with coefficients expressed as logit incidence rate ratios per 1 *SD* difference in personality trait. All regression models were adjusted for age, gender, and race/ethnicity, and all the personality traits were included in the same model, that is, they were mutually adjusted for each other. Results for models including one personality trait at a time (i.e. without mutually adjusting all the personality traits in the same model) are reported in the Supporting Information.

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The regression models were first fitted within each cohort separately. These estimates were then pooled to yield a single estimate across the cohorts by using fixed-effect meta-analysis. With a sample size of more than 56 000 participants, we had sufficient statistical power to detect even small effect sizes.

RESULTS

Descriptive statistics are shown in Table 1, and study years are shown in Table 2. Except for MIDJA and UKHLS, all the cohorts had up to three repeated measurements. Except for physical activity, the intraclass correlations of the variables across measurement times were moderately high (Table 3). For example, an intraclass correlation of 0.80 for BMI indicated that 80% of the total variance in BMI was due to the between-individual differences in average BMI across measurement times and only 20% was explained by within-individual variation over the participants' average BMI.

Table 2. Study years of the cohort studies

Cohort study	First wave	Second wave	Third wave
HILDA	2005	2009	2013
HRS*	2006/2008	2010/2012	2014
MIDJA	2008	2012	—
MIDUS	1995–1996	2003–2004	2013–2014
SOEP	2005	2009	2013
UKHLS	2005	2010–2012	—
WLSG	1992–1994	2003–2005	2011
WLSS	1992–1994	2003–2005	2011

Note: HILDA, Household, Income, and Labour Dynamics in Australia; HRS, Health and Retirement Study; MIDJA, Midlife in Japan; MIDUS, Midlife in the United States; SOEP, German Socio-economic Panel Study; UKHLS, UK Household Longitudinal Study; WLSG, Wisconsin Longitudinal Study with the graduate sample; WLSS, Wisconsin Longitudinal Study with the sibling sample.
*In HRS, half of the sample were administered personality inventories in 2006, 2010 and 2014 (three measurements), and the other half in 2008 and 2012 (two measurements).

In multilevel negative binomial regression, the sum of health risks was related to lower conscientiousness (1 *SD* difference in personality trait being associated with logit rate-ratio difference of B = −0.07, CI = −0.08, −0.06), lower emotional stability (B = −0.04, CI = −0.05, −0.03), lower openness to experience (B = −0.07, CI = −0.08, −0.06), and weakly with higher agreeableness (B = 0.01, CI = 0.001, 0.019) but not with extraversion (B = 0.003, CI = −0.006, 0.013). These associations represented how the sum of health risks was related to the weighted combination of (i) average differences in personality traits between different individuals and (ii) differences in personality traits within the same individuals across measurement times.

Figure 1 shows the associations of personality with the sum of health risks when the between-individual and within-individual associations are modelled as separate components in the regression model. The between-individual associations were all statistically significant, whereas the within-individual associations were much weaker and not statistically significant, with one exception: association of extraversion was statistically significant but in the opposite direction to the corresponding between-individual association.

Figure 2 shows the overall meta-analytic associations of personality with each of the health-risk variables when the between-individual and within-individual associations are not modelled as separate components. As expected, lower conscientiousness and emotional stability were associated with most health behaviours. Higher extraversion and lower agreeableness were associated with higher alcohol consumption. Figure 3 shows the separately modelled contributions of between-individual and within-individual

Table 3. Intraclass correlations (multiplied by 100) of the study variables

	HILDA	HRS	MIDJA	MIDUS	SOEP	UKHLS	WLSG	WLSS
Extraversion	74	69	74	68	60	58	74	75
Emotional stability	66	58	66	61	56	60	67	67
Agreeableness	66	62	63	64	51	46	62	61
Conscientiousness	69	61	63	60	52	45	62	63
Openness to Experience	70	68	70	66	58	55	71	69
Current smoker	83	78	75	64	77	77	58	61
Cigarettes per day	58	52	57	59	—	78	—	—
Physical inactivity	33	39	—	22	52	—	22	18
Drinks per week	69	71	68	64	45	—	60	63
Heavy consumption	53	46	46	53	45	—	34	37
Binge drinking	—	39	39	48	—	—	52	41
Body mass index	80	89	—	80	86	75	77	79
Number of participants with two or three measurement times								
Two	2427	6093	649	1564	5889	7583	2302	1518
Three	7024	3923	—	2463	9204	—	4070	2077
n (person-observations)	25 920	23 955	1292	10 517	39 381	14 991	16 789	9252

Note: The intraclass correlations were calculated using the analysis of variance estimator and then multiplied by 100 to omit decimal dots. HILDA, Household, Income, and Labour Dynamics in Australia; HRS, Health and Retirement Study; MIDJA, Midlife in Japan; MIDUS, Midlife in the United States; SOEP, German Socio-economic Panel Study; UKHLS, UK Household Longitudinal Study; WLSG, Wisconsin Longitudinal Study with the graduate sample; WLSS, Wisconsin Longitudinal Study with the sibling sample.

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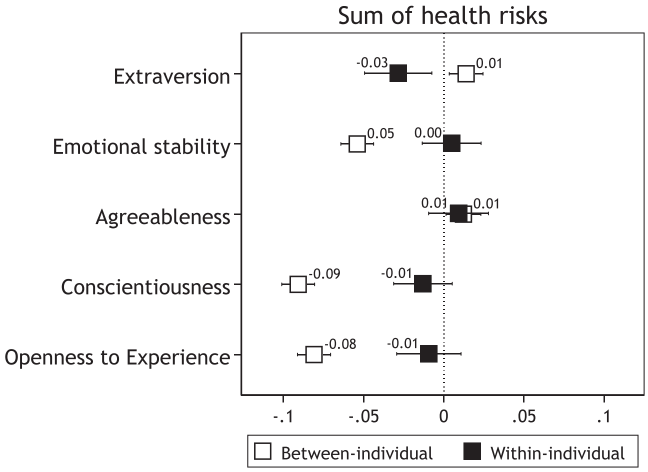

Figure 1. Between-individual and within-individual associations of personality traits with the sum score of physical inactivity, heavy alcohol consumption, smoking, and obesity (n = 46 059 participants with 32 203 participants contributing to the estimation of within-individual associations; Midlife in Japan and UK Household Longitudinal Study cohort were not included due to lack of data on some health indicators). Values are logit coefficients of incidence rate ratios (and 95% confidence intervals) of a negative binomial regression model. All associations were adjusted for age, sex, and race/ethnicity and the between-individual and within-individual associations of the other four personality traits.

associations that underlie the overall associations shown in Figure 2. Many of the between-individual associations were statistically significant and consistent with previously reported associations. By contrast, most of the within-individual associations were weaker and not statistically significant, thus not replicating the associations observed in the between-individual analysis. There were two exceptions: the within-individual associations between all five personality traits and physical inactivity were all statistically significant, and the within-individual association between extraversion and higher alcohol consumption was also significant.

Figures S1 to S24 show the study-specific associations for the pooled results reported earlier. Correlations between personality traits across studies are shown in Table S1. When the associations shown in Figures 2 and 3 were fitted separately for each personality trait, the conclusions remained mostly unchanged (Figures S25 to S32), except that the within-individual associations between extraversion and smoking (B = 0.07) and between conscientiousness and lower heavy alcohol consumption ($B = -0.09$) became statistically significant. Also, the unexpected association of higher agreeableness and higher risk of physical inactivity (Figure 2) appeared to be caused by mutual adjustment of the traits

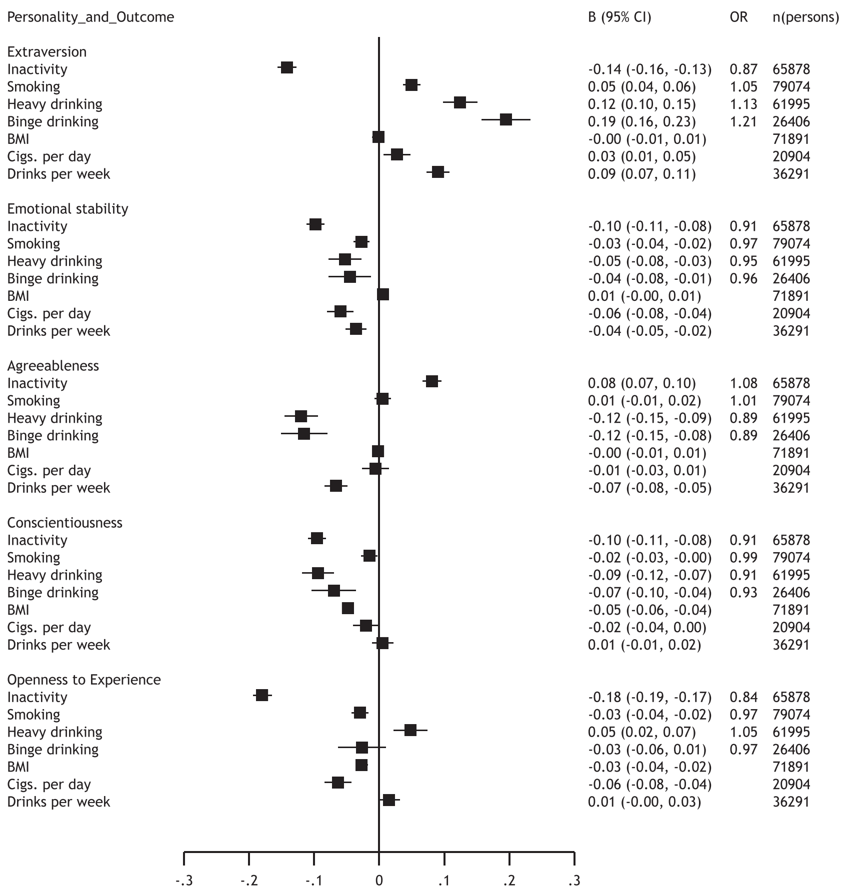

Figure 2. Overall associations between personality traits and health behaviours pooled across individual studies using fixed-effect meta-analysis. Values are logit coefficients of logistic regressions (for inactivity, smoking, and heavy and binge drinking) and standardized coefficients of linear regressions [standard deviations of body mass index (BMI), cigarettes per day, and drinks per week associated with 2 standard deviations of personality trait] and their 95% confidence intervals, with separate models fitted for each outcome. All associations were adjusted for the other four personality traits, age, sex, and race/ethnicity. OR, odds ratio.

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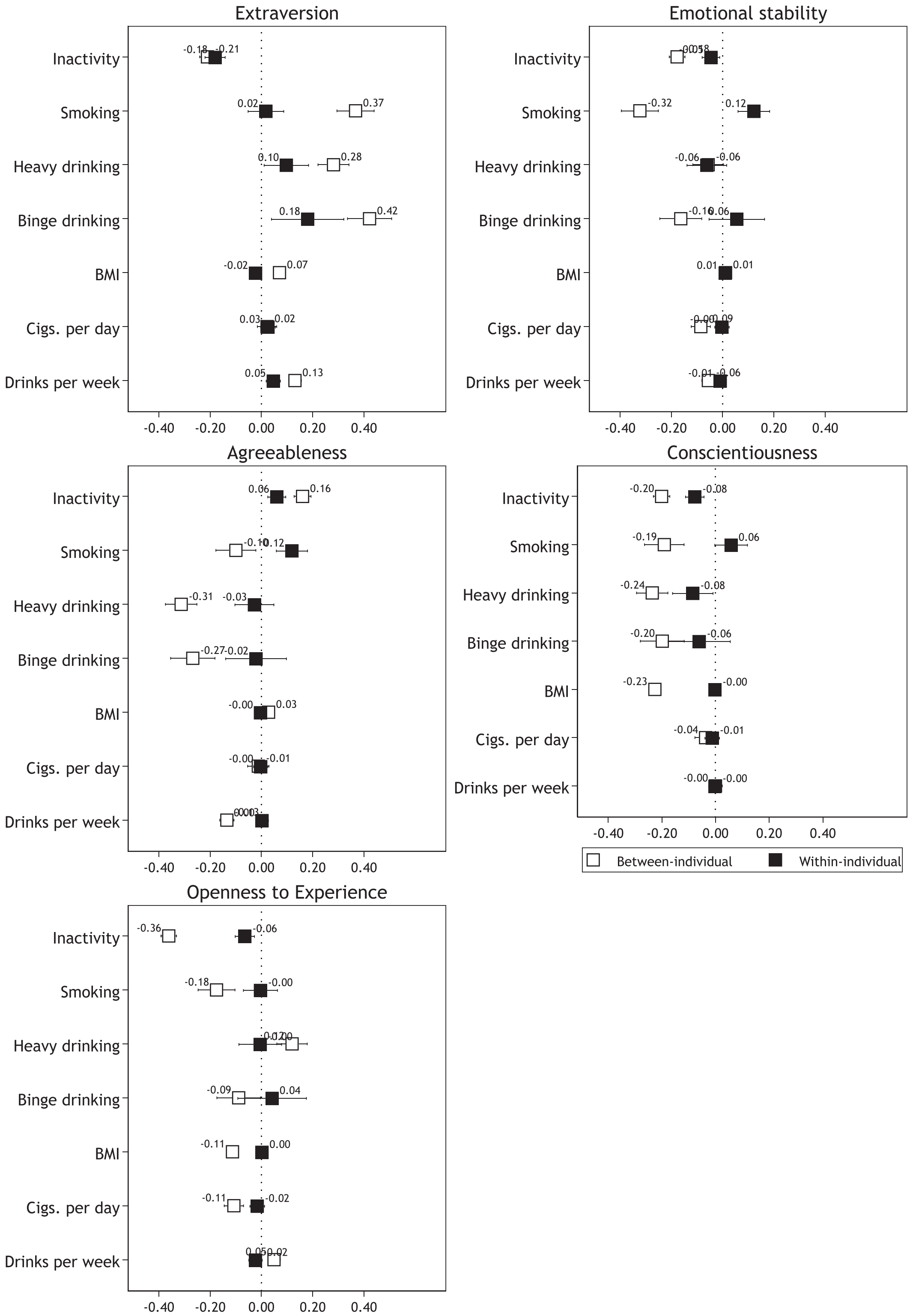

Figure 3. Between-individual and within-individual associations of personality traits with health behaviours (n = 12 356 to 56 671 participants). Values are logit coefficients of logistic regressions (for inactivity, smoking, and heavy and binge drinking) and standardized coefficients of linear regressions [standard deviations of body mass index (BMI), cigarettes per day, and drinks per week associated with 2 standard deviations of personality trait] and their 95% confidence intervals, with separate models fitted for each outcome. All associations were adjusted for the other four personality traits, age, sex, and race/ethnicity.

because when examined separately, physical inactivity was related to lower agreeableness (Figure S30). Figures S33 to S35 show the results of Figures 1–3 when adjusted for education (coded as 1 = primary, 2 = secondary, and 3 = tertiary education in each cohort). This did not have major effect on most of the associations of personality, expect for openness to experience for which the attenuations were larger. Figures S36 to S40 show the between-individual and within-individual associations adjusted for education but not for the other personality traits.

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DISCUSSION

To evaluate personality traits as potentially modifiable risk factors for health behaviours, we examined whether people's health behaviours change when their personality traits change naturally over time. We found only limited evidence for within-individual associations, suggesting that adult health behaviours are associated mostly with people's stable personality traits but less so with the variation in personality traits over time. This implies that these associations may not be causal in the sense that a change in personality trait would lead to changes in health behaviours. There were two exceptions to this pattern: Participants were more likely to be physically inactive in measurement times in which they were less extraverted, less emotionally stable, more agreeable, less conscientious, and less open to experience in comparison with their average personality levels. In addition, participants were more likely engage in risky alcohol consumption in times when their extraversion was higher than their average level of extraversion. Many health behaviours were associated with stable, between-individual personality differences, especially with low conscientiousness, emotional stability, agreeableness, and openness to experience and with high extraversion.

Our findings cast some doubt on the assumption that personality traits are modifiable, causal determinants of health behaviours. However, before drawing such a conclusion, it is important to consider study limitations and open questions that need to be addressed in future research. First, personality traits and health behaviours were measured only two or three times. Because of the more constrained variance, within-individual associations were estimated with more measurement error than between-individual associations. This might help to explain why within-individual associations were observed for physical inactivity, which showed the lowest levels of within-individual stability. However, the confidence intervals of all the within-individual estimates were not overly wide compared with the overall associations. We note that variation in personality traits across two or three measurement times is commonly used to study personality development, indicating that such changes are often considered substantial rather than as mere measurement error. Furthermore, sibling studies such as discordant twin-pair comparisons are based on a similar analysis as our current within-individual analysis (e.g. Kim, 2016). Despite the moderately high intraclass correlations in these studies, especially within monozygotic twin pairs (Bratko, Butkovic, & Hlupic, 2017), they are rarely criticized for not having more than two siblings from the same family.

Second, the majority of the participants were middle-aged individuals. Many health behaviours, smoking initiation in particular (Freedman, Nelson, & Feldman, 2012), are strongly determined already in young adulthood, and they remain somewhat stable over time (Jones, Hinkley, Okely, & Salmon, 2013). It is possible that early personality in adolescence and young adulthood does have a causal impact on how people adopt healthy or unhealthy behaviours (Hampson, Edmonds, Goldberg, Dubanoski, & Hillier, 2013, 2015), and people then tend to follow these early-set healthy trajectories. If this were the case, one would not expect changes in adult personality to lead to changes in health behaviours—the adult associations would only reflect the residue of the causal associations operating in adolescence and young adulthood. It is also possible that there is a time lag between personality change and changes in health behaviours, which our study design might not have detected. Third, we only examined naturally occurring variation and not experimentally induced change, and the results might be different with the latter.

Fourth, the associations between personality and health behaviours were cross-sectional, so the associations could be due to personality influencing health behaviour or health behaviour influencing personality (Allen, Vella, & Laborde, 2015; Jokela, Hakulinen, Singh-Manoux, & Kivimäki, 2014; Stephan, Sutin, & Terracciano, 2014). However, any reverse causality would probably have amplified rather than attenuated the associations because these bidirectional associations are likely to work in the same directions. For example, physical inactivity, smoking, and alcohol consumption have been associated with decreasing conscientiousness (Allen et al., 2015), but this would strengthen any associations of low conscientiousness on risky health behaviours in cross-sectional analyses. Fifth, the within-individual analysis does not eliminate unobserved confounding variables that vary within individuals over time, so some of the within-individual associations may still reflect confounding due to time-varying third variables (Gunasekara et al., 2014). Finally, the associations between personality and health behaviours might be related to specific personality facets or even lower level nuances instead of broad personality traits (e.g. Seeboth & Mõttus, 2018; Vainik, Mõttus, Allik, Esko, & Realo 2015), in which case the analysis of broad traits could be too coarse to observe the true causal associations that could be operating at a lower level. Most of the current studies used only brief measures of personality that were different across most of the studies, so we could not examine more nuanced analyses below the trait level.

Most of our results suggested that changes in adult personality might not produce changes in health behaviours. There were two notable exceptions. First, we observed systematic within-individual associations between physical inactivity and all of the Five Factor Model personality traits. Longitudinal studies have associated personality traits with physical activity measured several years later (Allen, Magee, Vella, & Laborde, 2017), and physical activity has also been associated with personality development over time (Stephan et al., 2014). It thus seems that physical activity is the most susceptible health behaviour related to personality differences. Given the previously reported bidirectional associations between personality and physical activity, our current findings cannot say whether the within-individual associations are due to changes in personality causing changes in physical activity, or vice versa, or whether they co-occur simultaneously.

Second, within-individual variation in extraversion was related to higher alcohol consumption. This could be because higher extraversion leads to increased social engagement, which then may lead to more frequent alcohol use in social

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occasions (Hakulinen, Elovainio, et al., 2015). Heavy alcohol consumption (but not alcohol problems) has also been associated with increasing extraversion over time (Hakulinen & Jokela, in press), so this within-individual association may also be due to bidirectional association similar to those observed for physical inactivity.

Some within-individual associations showed the opposite directions compared with their corresponding between-individual associations. On average, people who were smokers had lower emotional stability, lower agreeableness, and lower conscientiousness than non-smokers. But among smokers who changed their smoking status across measurement times, smoking was related to higher emotional stability, higher agreeableness, and higher conscientiousness. This might be due to the effects of smoking on decreasing anxiety and improving concentration on the one hand (Heishman, Kleykamp, & Singleton, 2010) and the withdrawal symptoms of increasing anxiety and irritability on the other hand (Taylor et al., 2014). More detailed measures of smoking cessation and withdrawal symptoms would be needed to test such time-varying associations of smoking.

Previous studies have examined interrelated changes of personality and health status across time, often examining correlations of change scores or parallel growth curves and finding that 'adverse' personality change is associated with increasing health problems (Human et al., 2012; Konradt, Hagemeyer, Neyer, & Kandler, 2018; Mroczek & Spiro, 2007) or vice versa (Jokela, Hakulinen, et al., 2014). In the MIDUS study (Turiano, Whiteman, Hampson, Roberts, & Morczek, 2012), increase in substance abuse was associated with concurrent increases in neuroticism and openness to experience and decreases in conscientiousness and agreeableness, which is mostly in line with a recent meta-analysis of alcohol use and personality change (Hakulinen & Jokela, 2018). Our results may differ from most of these studies because we focused on health behaviours rather than physical illnesses that may be driven by different dynamics (e.g. a person may develop type 2 diabetes but then start exercising, stop smoking, and reduce alcohol consumption to control the disease). Moreover, we examined how people's time-specific personality scores varied around their overall mean scores, whereas the previous studies have examined how people's personality changes from their baseline level. Further studies are needed to compare different methods of modelling personality change to test whether such methodological approaches produce different results and whether they relate to different causal mechanisms.

The focus of our study was on within-individual associations, but this is not to say that stable, between-individual associations would not be important. Individuals who had stable levels of higher extraversion, lower emotional stability, lower agreeableness, lower conscientiousness, and lower openness to experience were more likely to have risky health behaviours. Stable personality scores can still be informative in many ways, for example, in developing health risk profiles, selecting most promising intervention strategies, and predicting relapse risk in health interventions. The lack of within-individual associations does not reduce the predictive validity of personality traits; it is well known that aggregated scores of multiple measurements are more accurate indicators of underlying personality dispositions than single measurements (Epstein, 1983). The present quasi-experimental study design cannot be leveraged to gain insight on causality of between-individual measures but only on time-varying personality differences. Other quasi-experimental study designs are needed to test the causality of stable personality traits (Briley, Livengood, & Derringer, 2018; Constantini & Perugini, 2018; Lawlor et al., 2017; Mõttus, 2016; Zapko-Willmes, Riemann, & Kandler, 2018).

In conclusion, our analysis suggests that stable personality traits are consistently associated with multiple health behaviours. By contrast, naturally occurring changes in personality traits are weakly, if at all, associated with changes in health behaviours—physical activity being a notable exception. This implies that adult personality traits may not be modifiable, causal risk factors for most health behaviours. Additional experimental and quasi-experimental evidence from different study designs is needed to support or refute the current conclusions from the within-individual analysis.

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CONFLICTS OF INTEREST

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Overall associations of personality traits with sum of health risks.
Figure S2. Between-individual associations of personality traits with sum of health risks.
Figure S3. Within-individual associations of personality traits with sum of health risks.
Figure S4. Overall associations of personality traits with physical inactivity.
Figure S5. Between-individual associations of personality traits with physical inactivity.
Figure S6. Within-individual associations of personality traits with physical inactivity.
Figure S7. Overall associations of personality traits with smoking.
Figure S8. Between-individual associations of personality traits with smoking.
Figure S9. Within-individual associations of personality traits with smoking.
Figure S10. Overall associations of personality traits with heavy drinking.
Figure S11. Between-individual associations of personality traits with heavy drinking.
Figure S12. Within-individual associations of personality traits with heavy drinking.
Figure S13. Overall associations of personality traits with binge drinking.
Figure S14. Between-individual associations of personality traits with binge drinking.
Figure S15. Within-individual associations of personality traits with binge drinking.
Figure S16. Overall associations of personality traits with BMI.
Figure S17. Between-individual associations of personality traits with BMI.
Figure S18. Within-individual associations of personality traits with BMI.
Figure S19. Overall associations of personality traits with cigarettes per day.
Figure S20. Between-individual associations of personality traits with cigarettes per day.
Figure S21. Within-individual associations of personality traits with cigarettes per day.
Figure S22. Overall associations of personality traits with drinks per week.
Figure S23. Between-individual associations of personality traits with drinks per week.
Figure S24. Within-individual associations of personality traits with drinks per week.
Figure S25. Overall associations with sum of health risks unadjusted for other traits
Figure S26. Between-individual associations with sum of health risks unadjusted for other
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Figure S28. Pooled associations of extraversion when not adjusted for other traits
Figure S29. Pooled associations of emotional stability when not adjusted for other traits
Figure S30. Pooled associations of agreeableness when not adjusted for other traits
Figure S31. Pooled associations of conscientiousness when not adjusted for other traits
Figure S32. Pooled associations of openness to Experience when not adjusted for other traits
Figure S33. Between-individual and within-individual associations of personality traits with the sum score of physical inactivity, heavy alcohol consumption, smoking, and obesity (n = 46,059 participants with 32,203 participants contributing to the estimation of within-individual associations); MIDJA and UKHLS cohort were not included due to lack of data on some health indicators). Values are logit coefficients of incidence rate ratios (and 95% confidence intervals) of a negative binomial regression model. All associations were adjusted for education, age, sex, and race/ethnicity and the between-individual and within-individual associations of the other four personality traits.
Figure S34. Overall associations between personality traits and health behaviors pooled across individual studies using fixed-effect meta-analysis. Values are logit coefficients of logistic regressions (for inactivity, smoking, and heavy and binge drinking) and standardized coefficients of linear regressions (standard deviations of BMI, cigarettes per day, and drinks per week associated with 2 standard deviations of personality trait) and their 95% confidence intervals, with separate models fitted for each outcome. OR = odds ratio. All associations were adjusted for education, the other four personality traits, age, sex, and race/ethnicity.

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Figure S35. Between-individual and within-individual associations of personality traits with health behaviors (n = 12,356 to 56,671 participants). Values are logit coefficients of logistic regressions (for inactivity, smoking, and heavy and binge drinking) and standardized coefficients of linear regressions (standard deviations of BMI, cigarettes per day, and drinks per week associated with 2 standard deviations of personality trait) and their 95% confidence intervals, with separate models fitted for each outcome. All associations were adjusted for education, the other four personality traits, age, sex, and race/ethnicity.
Figure S36. Pooled associations of extraversion adjusted for education but not for other traits
Figure S37. Pooled associations of emotional stability adjusted for education but not for other traits
Figure S38. Pooled associations of agreeableness adjusted for education but not for other traits
Figure S39. Pooled associations of conscientiousness adjusted for education but not for other traits
Figure S40. Pooled associations of openness to Experience adjusted for education but not for other
Table S1. Correlations between personality traits, averaged across all study samples (n = up to 77,171 participants)
Table S2. Variable names of the study variables in the datasets

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