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Citation for final published version:

White, Jamie, Kivimaki, Mika and Batty, G. David 2018. Changes in health behaviors and longevity. *Epidemiology* 29 (4) , e26-e27.
10.1097/EDE.0000000000000824 file

Publishers page: <http://dx.doi.org/10.1097/EDE.0000000000000824>
<<http://dx.doi.org/10.1097/EDE.0000000000000824>>

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Type of manuscript: Research letter

Manuscript title: Changes in Health Behaviors and Longevity

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Manuscript statistics: 600 words, 1 table, 6 references

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Running head: none

Conflict of interest statement: The authors have no conflicts of interest to declare.

Sources of financial support: The results reported herein correspond to specific aims of grant MR/KO232331/1 to investigator Prof Campbell from British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the Welsh Government and the Wellcome Trust, under the auspices of the UK Clinical Research Collaboration (Dr White). All funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data availability: The data are available from the UK Data Archive (<https://discover.ukdataservice.ac.uk/>).

To the Editor:

Smoking, excess alcohol intake, physical inactivity, and low fruit and vegetable consumption, are well-documented risk factors for mortality.¹⁻⁴ Very few studies have, however, examined the association between changes in these behaviors and future mortality. Randomized trials have found smoking cessation reduces mortality risk.¹ Observational studies suggest changes in physical activity are associated with mortality risk,² but for fruit and vegetable and alcohol consumption the evidence is mixed.^{3,4} These studies have also examined changes in isolation but unhealthy changes in behavior may offset any beneficial effects accrued from healthy changes. For instance, smoking cessation is associated with around 4.7 kgs (10.4 lbs) weight gain after 12 months,⁵ and reductions in caloric intake may be compensated by concomitant reductions in physical activity.⁶ This study examined the associations of both healthy and unhealthy changes in behavior with the risk of all-cause mortality.

We used data from the Health and Lifestyle Survey I (1984/5) and II (1991-1992), a prospective cohort of residents in England, Wales, and Scotland aged ≥ 18 years in 1984. The study was approved by local ethics committees. An interviewer assessed participants' current smoking status, alcohol consumption (≥ 14 per week for women/ ≥ 21 units for men), physical activity (≥ 2 hours a week), and fruit and vegetables consumption (≥ 3 times a day over the past year). Healthy and unhealthy changes between survey I and II were coded. We compared rates of mortality from all-causes between people making healthy and unhealthy changes using Cox proportional hazards models adjusted for other changes in behaviors, demographics, occupational social class (including an unemployed category) and physical health conditions. We imputed missing data using multiple imputation to generate 10 datasets. We checked the proportional hazards assumption for Cox models using Schoenfeld

residuals and found it was unviolated. Analyses were done using Stata (StataCorp), version 13.0.

Of the 9,003 baseline participants (74% of those recruited in survey I), 5,352 (59%) also took part in survey II. We excluded study members who had died between surveys (n= 880), resulting in an analytical sample of 8,123 (4,666 women, median age, 41 years [interquartile range, 30-56] with 2,003 deaths occurring over a median follow-up of 7 years [interquartile range, 6-7]) (Table). The risk of mortality was associated with increases (model 2 hazard ratio [HR] = 0.9, 95% confidence interval [CI] = 0.8-1.0) and decreases (model 2 HR = 1.1, 95% CI: 0.9-1.3) in physical activity, and reductions in fruit and vegetable consumption (model 2 HR = 1.3, 95% CI = 1.0-1.7). Changes in smoking status and alcohol consumption were not related to mortality rates. Sensitivity analyses in samples excluding people with missing data (n = 3,163), physical illness (n = 6,753), who died within five years of 1991/2 (n = 7,350) and with minimal adjustments produced the same pattern of results (eTables 1 to 4).

In this study, changes in physical activity and decreases in fruit and vegetable consumption were weakly associated with all-cause mortality. These findings confirm those from smaller studies suggesting modest increases in physical activity are associated with a 30%-40% reduction in mortality² and are in agreement with the PREDIMED trial which found decreases in mortality after increases in fruit consumption.³ We found no clear association between changes in smoking status or alcohol consumption with mortality risk. The benefits of smoking cessation have generally been found in populations older than those in the present study.¹ Limitations of our work include misclassification of participants if behaviors changed after survey II and survivor bias whereby more healthy participants survived until the

resurvey and were included, which may have underestimated associations. These observational data do not provide evidence of causality.

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Table. Changes in Health Behaviors in relation to All-Cause Mortality (n = 8,123)

	Hazard ratio (95% CI)		
	% (n)	Model 1 ^a	Model 2 ^b
Healthy changes in behavior ^c			
Smoking cessation (1984/5: current; 1991/2: never/former)	14.7 (1193)	1.0 (0.8, 1.3)	1.0 (0.8, 1.3)
Decrease alcohol consumption (1984/5: $\geq 14/21$ units; 1991/2 $< 14/21$ units)	12.5 (1016)	0.9 (0.7, 1.2)	0.9 (0.7, 1.1)
Increase fruit and vegetable intake (1984/5: < 3 times/day; 1991/2 ≥ 3 times/day)	10.8 (878)	1.0 (0.9, 1.1)	1.0 (0.8, 1.1)
Increase physical activity (1984/5: < 2 hrs/ week; 1991/2 ≥ 2 hrs /week)	48.4 (3932)	0.8 (0.7, 0.9)	0.9 (0.8, 1.0)
Unhealthy changes in behavior ^d			
Start smoking (1984/5: never/former; 1991/2: current)	7.8 (634)	1.1 (0.8, 1.4)	1.1 (0.8, 1.4)
Increase alcohol consumption (1984/5: $< 14/21$ units; 1991/2 $\geq 14/21$ units)	7.2 (585)	1.0 (0.8, 1.4)	1.0 (0.8, 1.4)
Decrease fruit/ vegetable intake (1984/5: ≥ 3 times/day; 1991/2 < 3 times/day)	10.7 (867)	1.2 (0.9, 1.6)	1.3 (1.0, 1.7)
Decrease physical activity (1984/5: ≥ 2 hrs /week; 1991/2 < 2 hrs/ week)	16.9 (1373)	1.2 (1.0, 1.3)	1.1 (0.9, 1.3)

^a Model 1 adjusted for changes in other behaviors, baseline age, sex and ethnicity.

^b Model 2 adjusted for changes in other behaviors, baseline age, sex, ethnicity, occupational social class, marital status, body mass index, systolic blood pressure, diastolic blood pressure, force expiratory volume in 1 second, simple reaction time, choice reaction time, memory index score, visual spatial reasoning score, diagnoses of a heart condition/ stroke, respiratory disease, diabetes, gastrointestinal disease, and arthritis.

^c Reference group for healthy changes were: current smoker 1984/5 & 1991/2, $\geq 14/21$ units alcohol 1984/5 & 1991/2, fruit and vegetables < 3 times/day 1984/5 & 1991/2, and < 2 hrs/ week physical activity 1984/5 & 1991/2.

^d Reference group for unhealthy changes were: Never/former smoker 1984/5 & 1991/2, $< 14/21$ units alcohol 1984/5 & 1991/2, fruit and vegetables ≥ 3 times/day 1984/5 & 1991/2, and ≥ 2 hrs /week physical activity 1984/5 & 1991/2.