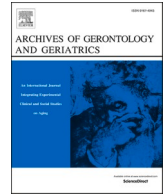




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## Individual mental health patterns and the role of lifestyle among ageing adults over 20 years - the Doetinchem Cohort Study

M Menassa<sup>a,b,c,e,\*</sup>, KEJ Wesenhagen<sup>c</sup>, K Stronks<sup>d</sup>, OH Franco<sup>e</sup>, WMM Verschuren<sup>c,e</sup>, HSJ Picavet<sup>c</sup>

<sup>a</sup> Institute of Social and Preventive Medicine, University of Bern, Mittelstrasse 43, Bern 3012, Switzerland

<sup>b</sup> Graduate School for Health Sciences, University of Bern, Bern, Switzerland

<sup>c</sup> Centre for Nutrition, Prevention and Health Services, National Institute for Public Health and the Environment, the Netherlands

<sup>d</sup> Department of Public and Occupational Health, Amsterdam University Medical Centers, University of Amsterdam, Amsterdam, the Netherlands

<sup>e</sup> Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, the Netherlands

### HIGHLIGHTS

- Good and changing mental health patterns are more common than poor mental health in a sample of Dutch adults followed over 20 years.
- Changing and poor mental health patterns are associated with long-term unhealthy patterns of smoking and sleep.
- Understanding the mechanisms and the directions of associations between long-term mental health and lifestyle patterns could help devise better interventions to improve mental health.

### ARTICLE INFO

#### Keywords:

Cohort  
Lifestyle  
Mental health  
Sleep  
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### ABSTRACT

**Objective:** We explored the prevalence of individual mental health patterns and the role of lifestyle factors over 20 years.

**Study design:** We used data from the Doetinchem Cohort Study (1995–2019), a population-based study amongst adults (26–90 years) examined every five years in the Netherlands. Participants were classified in five pre-defined mental health patterns (persistent good, persistent poor, worsening, improving, varying) over 20 years (five rounds) using the MHI-5 questionnaire. BMI, sleep, smoking, alcohol consumption, and physical activity were dichotomised as healthy/unhealthy based on guidelines. The role of lifestyle at baseline (t1), 20 years later (t5), and longitudinally over 20 years (using pre-defined patterns) was explored using logistic regression.

**Results:** Most participants had good mental health at t1 (85 %) and t5 (88 %). Over 20 years, 67 % followed a persistent good mental health pattern, 30 % a changing pattern, and 3 % a persistent poor pattern. Persistent poor and changing patterns were associated with unhealthy sleep and smoking at t1, t5, and with the 20-year unhealthy patterns. Persistent poor mental health was associated with stable unhealthy and changing sleep (OR=5.58(2.48–12.54) and OR=2.07(1.14–3.74), respectively), and with stable unhealthy and changing smoking (OR=3.35(1.58–7.11) and OR=2.53(1.40–4.57), respectively). Changing mental health was associated with changing (OR=1.54(1.26–1.88) and OR=1.64(1.30–2.07), respectively) and stable unhealthy (OR=1.80(1.23–2.64) and OR=2.24(1.60–3.14), respectively) sleep and smoking, respectively.

**Conclusions:** Persistent good and changing mental health patterns were more common than poor mental health in adults and were associated with smoking and sleep. Clarifying the underlying mechanisms and directionality between mental health and lifestyle could improve interventions.

**Abbreviations:** Body Mass Index, BMI; 5-item Mental Health Inventory, MHI-5; Short Form Health Survey, SF-36; The Doetinchem Cohort Study, DCS.

\* Corresponding author.

**E-mail addresses:** [marilyne.menassa@ispm.unibe.ch](mailto:marilyne.menassa@ispm.unibe.ch), [m.menassa@umcutrecht.nl](mailto:m.menassa@umcutrecht.nl) (M. Menassa).

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### 1. Introduction

Mental health can be defined as a “state of mind characterized by emotional well-being, good behavioural adjustment, relative freedom from anxiety and disabling symptoms, and a capacity to establish constructive relationships and cope with the ordinary demands and stresses of life” (Association, 2023). Mental health can change throughout the life course, creating patterns that vary within and between individuals and across populations, times, and contexts (Prior, Jones & Manley, 2020; Twenge, 2015). Long-term patterns of individual changes in mental health generally include a good pattern, a poor pattern, and changing patterns, although variations by study exist (Bromberger et al., 2019; Engel et al., 2020; Lincoln & Takeuchi, 2010; Kuchibhatla et al., 2012; Holden, Ware & Lee, 2016; Paksarian et al., 2016).

Human behaviour is rooted in sociocultural, psychological, and cognitive dimensions that evolve and change throughout life. Elder’s life course theory for example, highlights timing, context, opportunity, and agency in determining the individual’s faring in life. Additionally, a recent systematic review of 192 epidemiological studies identified the median age at onset of mental disorders including depression, before the age of thirty-five (Solmi et al., 2022). This highlights the importance of understanding from early life, the determinants of mental health for primary prevention. Because of their modifiable nature, lifestyle factors have gained attention in relation to mental health (Merlo & Vela, 2022). Most studies describe how mental health outcomes or patterns are associated with lifestyle factors, mainly at one point in time. For example, healthy behaviours for sleep, BMI, and physical activity have been associated with better mental health (Zhai, Zhang & Zhang, 2015; Silva et al., 2020; Pearce et al., 2022; Luppino et al., 2010). Evidence is less consistent for alcohol intake and smoking (Maier et al., 2021). Some studies also highlight bidirectional associations between obesity or smoking and mental health (Luppino et al., 2010; Fluharty et al., 2017). How long-term mental health patterns are related to long-term lifestyle patterns is thus not evident in the literature.

This paper aims to fill this gap based on data from the Doetinchem Cohort Study (DCS) in the Netherlands. First, we explore the prevalence of mental health patterns over the adult life, and second, we investigate

the factors associated with these patterns including long-term lifestyle patterns for BMI, alcohol consumption, smoking, physical activity, and sleep.

### 2. Methods

#### 2.1. Study population

The DCS is a population-based longitudinal study that explores the impact of lifestyle and biological risk factors on health (Picavet et al., 2017). Between 1987 and 1991 (round 1), data (questionnaires/physical examination) were collected for 12,405 participants, based on a sex- and age-stratified sample of the 20–59-year-olds from Doetinchem’s general population. Two-thirds of the participants (n = 7768) were approached for a second measurement and then every five years. To date, six rounds have been completed and the seventh round is ongoing (78 % average participation rate). Because mental health data have been collected starting 1995, we redefined the measurement rounds into five time-points (Fig. 1): 1995–1999 (t1, study baseline), 2000–2004 (t2), 2005–2009 (t3), 2010–2014 (t4), and 2015–2019 (t5, study final follow-up). We included participants from t5 (n = 3449) for whom the mental health patterns could be defined (n = 2710). Participants (n = 261) were excluded because we did not have enough measurements to clearly determine their long term patterns of mental health. The study was approved by the Medical Ethics Committee of the University Medical Center Utrecht including written informed consent from participants.

#### 2.2. Mental health

Mental health was assessed using the Dutch version of the 5-item Mental Health Inventory (MHI-5) of the Short Form Health Survey (SF-36), with the questions: *Over the last four weeks how often (i) Have you felt so down in the dumps that nothing could cheer you up? (ii) Have you felt downhearted and blue? (iii) Have you been a happy person? (iv) Have you been a very nervous person? (v) Have you felt calm and peaceful?* Each item had six response categories from ‘all the time’ (1 point) to ‘none of the time’ (6 points). The score ranged from 0 (poorest) to 100 (optimal). In

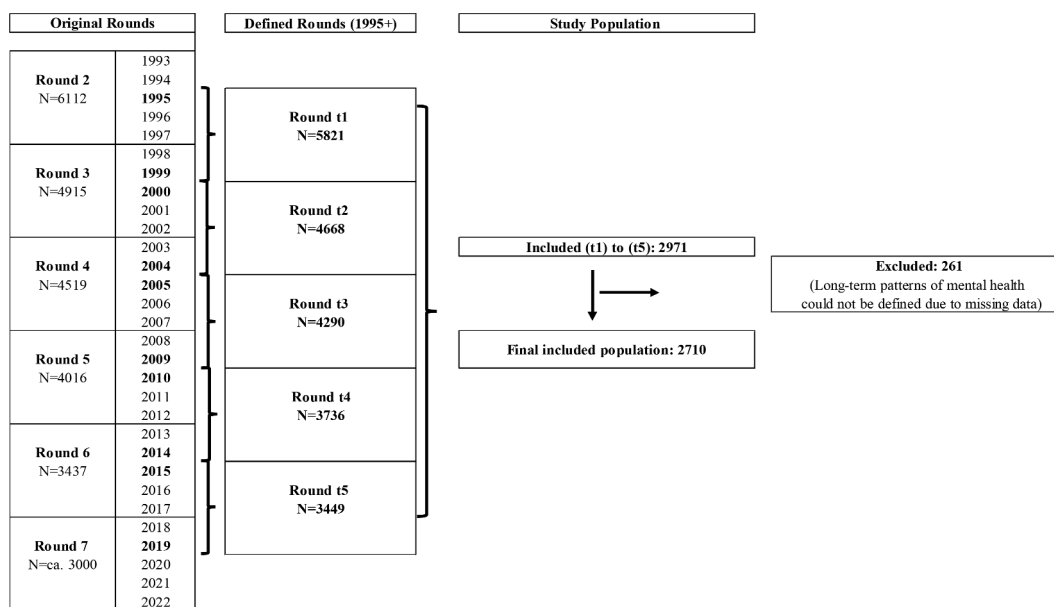


Fig. 1. Definition of rounds and sample selection. The original 5-year rounds are defined based on two-thirds randomly selected participants from baseline. The defined 5-year timepoints (t1, t2, t3, t4, t5) are based on the first available data for mental health starting in 1995. The study population is based on included participants at t1 and t5 for which long-term mental health patterns could be defined. Participants were excluded when the long-term mental health patterns could not be defined due to missing data from the other timepoints.

the absence of a standard cut-off, mental health status was dichotomized at 60 as good or poor ( $\leq 60$ ). With this cut-off, the percentage of individuals with poor mental health was closest to the percentage with a mental disorder, based on a diagnostic interview in a representative sample of Dutch adults (Perenboom et al., 2000). MHI-5 scores correlate well with other mental health tools and with diagnostic interviews for psychiatric disorders, particularly for mood and anxiety, with a good reliability in the general population (Cronbach's  $\alpha$  0.88) (McCabe et al., 1996; Rumpf et al., 2001).

### 2.3. Lifestyle factors

Smoking status, physical activity, sleep duration, and alcohol consumption were self-reported (Picavet et al., 2017). BMI was based on measured height (m) and weight (kg). Lifestyle factors per round were dichotomized as healthy or unhealthy based on guidelines: smoking (healthy as non-smoker/ex-smoker or unhealthy as current smoker), physical activity (healthy as adherence to 30 min/day (210 mins/week) on average of moderate or high intensity physical activity or unhealthy as nonadherence), BMI (healthy  $< 25 \text{ kg/m}^2$  or unhealthy  $\geq 25 \text{ kg/m}^2$ ), sleep (healthy as 7–8 h/night on average or unhealthy as  $< 7$  h or  $> 8$  h/night), and alcohol consumption (healthy as  $\leq 1$  glass/day on average or unhealthy as  $> 1$  glass/day on average) (Watson et al., 2015; Kemper, Ooijendijk & Stiggelbout, 2000).

### 2.4. Sociodemographic and health factors

Sex and education level (low, i.e., intermediate secondary education or less, intermediate, i.e., intermediate vocational/higher secondary education, high, i.e., higher vocational education/university) were collected at t1 and t2. Age was categorized into three 15-year categories at t1 (26–40, 41–55, 56–70) and t5 (45–60, 61–75, 76–91) years. Household (living/not living with partner) and work (employed/unemployed) status were self-reported at t1 and t5. A composite chronic diseases variable (diabetes, COPD/Asthma, and history of cardiovascular diseases (myocardial infarction and/or stroke) and cancer) were collected at t1 and t5. Diabetes was self-reported as diagnosed by doctor and/or non-fasting blood glucose levels ( $\geq 11.1 \text{ mmol/l}$ ). Airway symptoms for asthma and/or COPD were self-reported based on wheezing, shortness of breath, and/or coughing complaints. Physical functioning was measured with the SF-36, including limitations in daily activities such as washing, dressing, walking, bowing, stair climbing, lifting, vacuuming, cycling, and running (Ware & Sherbourne, 1992). The standard score was calculated and dichotomized, with no physical limitation defined as scale  $\geq 88$ . Pain was based on the SF-36 questions for pain intensity and limitations of usual work (last 4 weeks) and dichotomized, with no pain defined as scale  $\geq 68$ . Pain and physical limitations cut-offs were based on their distributions in our sample in the absence of standard cut-offs.

### 2.5. Statistical analyses

Mental health and lifestyle patterns were pre-defined based on previous studies (Lincoln & Takeuchi, 2010; Kuchibhatla et al., 2012; Holden, Ware & Lee, 2016; Paksarian et al., 2016; Schermer & al., 2022). We used pre-defined instead of data-driven patterns because the latter are highly dependant on the study samples which limits comparability, and because pre-defined patterns results are easier to interpret and more useful for policy. The dichotomized MHI-5 scores from each timepoint were used to define five patterns: persistent good (good mental health at all timepoints), persistent poor/almost always poor (poor mental health in at least four timepoints including t1 and t5), worsening pattern (good mental health at t1 followed by, and ending with poor mental health), improving pattern (poor mental health at t1 followed by, and ending with good mental health). The varying pattern included participants who did not fit other patterns (Table 2). To

improve sample power and for simplification, we combined worsening, improving, and varying under one changing pattern. Similarly, five lifestyle patterns were pre-defined as stable healthy, stable unhealthy, worsening, improving, and varying (the latter three combined as one changing pattern).

The characteristics of the study population were described and the prevalence of the five mental health patterns was determined. Univariate and multivariate logistic regressions were conducted to determine the cross-sectional associations between three mental health patterns (persistent good (reference group), persistent poor, and changing) and lifestyle factors at t1 and t5, adjusted for sociodemographic and health characteristics. Finally, for the associations between long-term mental health and lifestyle patterns, a three-step model reduction approach was used. The initial fully adjusted model included the covariates age(t5), sex, employment status(t5), household status(t5), educational level (t2, which is the most recent available round for education), physical functioning(t5), pain(t5), and presence of chronic diseases(t5). The final model was adjusted for age at final follow-up(t5), sex, household status (t5), chronic disease(t5), and physical functioning(t5) as these showed significant associations in our models and were not highly correlated ( $r < 0.4$ ). All analyses were performed using SAS 9.4 (significant p-value  $< 0.05$  unless indicated otherwise).

### 2.6. Exploratory analyses

As previous research showed sex-dependant differences in risk factors and mental health disorders, we tested for interaction effects between lifestyle factors and sex on mental health patterns (considered significant at p-value  $< 0.1$  of the likelihood ratios comparing models with and without the interaction) (Riecher-Rössler, 2017). Finally, we explored associations of all five (including improving, worsening, and varying) mental health patterns with lifestyle patterns.

## 3. Results

### 3.1. Sample characteristics

Our study included a total of 2971 participants who participated both at baseline (t1) and at follow-up (t5), of which 2710 (91 %) had data available for the long-term mental health patterns. At t1, more participants were employed while most were unemployed/retired at t5. At both timepoints, most did not have chronic disease, pain, or physical functioning problems. For all lifestyle factors (except BMI) at t1 and t5, most participants were healthy. Over 20 years, the most prevalent lifestyle patterns were stable healthy for each of sleep (44 %), alcohol consumption (42 %), and smoking (70 %); stable unhealthy (43 %) for BMI, and varying (35 %) for physical activity (Table 1).

### 3.2. Mental health patterns over 20 years

At t1 and t5, most participants had a good mental health (85 % and 88 % respectively) (Table 1). Over 20 years, most (67 %) had a persistent good mental health pattern, 30 % had a changing pattern, and 3 % had a persistent poor pattern (Table 2/ Fig. 2). The changing and persistent poor patterns were more often found amongst women, younger groups, and those living alone, with chronic diseases, or reporting pain at both timepoints. For all factors, the associations held for both timepoints. At both timepoints, the odds were higher for persistent poor than for changing mental health. Changing and persistent poor patterns were more often found in participants reporting high physical limitations, only at t5 (Table 3).

### 3.3. Mental health associations with lifestyle factors over 20 years

At t1 and t5, persistent poor and changing mental health patterns were associated with smoking and unhealthy sleep. The highest odds

**Table 1**  
Sociodemographic, lifestyle, health, and mental health characteristics at baseline (t1) and 20-year follow-up (t5).

	Baseline Round (t1) (n = 2710) %	Follow-up Round (t5) (n = 2710) %
<b>Female</b>	54 %	54 %
<b>Age categories</b>		
t1:26–40 years	32 %	30 %
t1:41–55 years	53 %	54 %
t1:56–70 years	15 %	16 %
<b>Living with a partner</b>	90 %	78 %
<b>Educational level</b>		
Low	45 %	42 %
Intermediate	30 %	32 %
High	25 %	27 %
<b>Unemployed</b>	30 %	59 %
<b>No chronic diseases</b>	81 %	62 %
<b>Low pain (&gt;=68)</b>	72 %	65 %
<b>Low physical limitation (&gt;=88)</b>	74 %	61 %
<b>Smoker</b>	24 %	10 %
<b>Physical activity (at least 210 min/week)</b>	63 %	61 %
<b>BMI</b>		
Normal/Underweight (< 25 kg/m <sup>2</sup> )	54 %	37 %
Overweight (25–30 kg/m <sup>2</sup> )	38 %	45 %
Obese (≥ 30 kg/m <sup>2</sup> )	8 %	18 %
<b>Sleep</b>		
Short (< 7 h)	16 %	23 %
Moderate (7–8 h)	80 %	71 %
Long (> 8 h)	5 %	6 %
<b>Low alcohol consumption (≤1 alcoholic beverage/day)</b>	62 %	68 %
<b>Smoking patterns n(t1-t5) = 2674</b>		
Stable healthy (non-smoker)	70 %	
Stable unhealthy	9 %	
Changing	21 %	
<b>Physical activity patterns n(t1-t5) = 2828</b>		
Stable healthy (active for at least 210 min/week)	29 %	
Stable unhealthy	12 %	
Changing	59 %	
<b>BMI patterns n(t1-t5) = 2815</b>		
Stable healthy (< 25 kg/m <sup>2</sup> )	26 %	
Stable unhealthy	43 %	
Changing	31 %	
<b>Sleep patterns n(t1-t5) = 2731</b>		
Stable healthy (>7 h per night)	44 %	
Stable unhealthy	8 %	
Changing	49 %	
<b>Alcohol consumption patterns n(t1-t5) = 2578</b>		
Stable healthy (≤1 alcoholic beverage/day)	42 %	
Stable unhealthy	25 %	
Changing	33 %	
<b>*MHI-5</b>		
Good mental health (>60)	85 %	88 %

\*Pain scale, physical scale and MHI-5 are subscales from SF-36 questionnaire.

were for persistent poor mental health and sleep at t1 (OR=2.14 (1.28–3.58)) and smoking at t5 (OR=2.21(1.12–4.36)). Changing mental health was associated with physical activity only at t5 (OR=1.36 (1.13–1.65)) (Table 3). For the long-term patterns of lifestyle, univariate analyses showed some associations between the persistent poor/ changing mental health patterns and the stable unhealthy/ changing lifestyle patterns. Mainly, changing mental health was associated with changing and stable unhealthy sleep, physical activity, and smoking, with highest odds for stable unhealthy sleep (OR=2.40(1.73–3.33)) and stable unhealthy smoking (OR=2.83(2.11–3.80)). Persistent poor mental health was associated with stable unhealthy sleep, alcohol consumption, and smoking and with changing patterns of sleep and smoking, with the highest odds for stable unhealthy sleep (OR=6.85

**Table 2**  
Prevalence of mental health patterns over 20 years.

*Mental Health Pattern (N = 2710)	Mental Health Status (Rounds t1-t5)					Prevalence %
	t1	t2	t3	t4	t5	
Persistent good (n = 1803)	Good	Good	Good	Good	Good	67 %
Persistent poor (n = 85)	Poor	Poor/ Good/ Missing	Poor	Poor	Poor	3 %
	Poor	Poor	Poor/ Good/ Missing	Poor	Poor	
Worsening (n = 112)	Poor	Poor	Poor	Poor/ Good/ Missing	Poor	4 %
	Good	Good	Poor/ Good/ Missing	Poor	Poor	
	Good	Good	Good	Poor/ Good/ Missing	Poor	
Improving (n = 196)	Poor	Poor/ Good/ Missing	Good	Good	Good	7 %
	Poor	Poor	Poor/ Good/ Missing	Good	Good	
Varying (n = 514)	Changing (at least 2 changes from Poor/Good or vice versa, and not in other subgroups)					19 %
	Changing (n = 822)	Worsening/Improving/ Varying				

\*Mental health status is defined as good when MHI-5 score > 60 and as poor when MHI-5 score ≤ 60.

(3.38–13.88)) and stable unhealthy smoking (OR=5.53(3.03–10.10)). In the multivariate model containing all lifestyle factors and adjusted for sociodemographic and health factors, the associations of changing and persistent poor mental health patterns remained only for changing and stable unhealthy sleep and smoking patterns. The highest odds were for the associations of persistent poor mental health with stable unhealthy sleep (OR=5.58(2.48–12.54)) and stable unhealthy smoking (OR=3.35 (1.58–7.11)). There was also an inverse association between persistent poor mental health and stable unhealthy BMI (OR=0.50(0.27–0.93)) (Table 4).

### 3.4. Interaction and exploratory analyses

There were no statistically significant interactions between sex and any of the lifestyle factors on mental health patterns. Exploratory analyses of the five mental health patterns showed overall similar associations compared to the models with three mental health patterns combined (Supplement 1).

## 4. Discussion

We explored the 20-year prevalence of individual mental health patterns in a sample of Dutch adults. Persistent good mental health was the most common pattern, one third had a changing pattern, and 3 % had a persistent poor pattern. Persistent poor and changing mental health were positively associated with smoking and unhealthy sleep at baseline, at final follow-up, and during the 20-year period. For the other

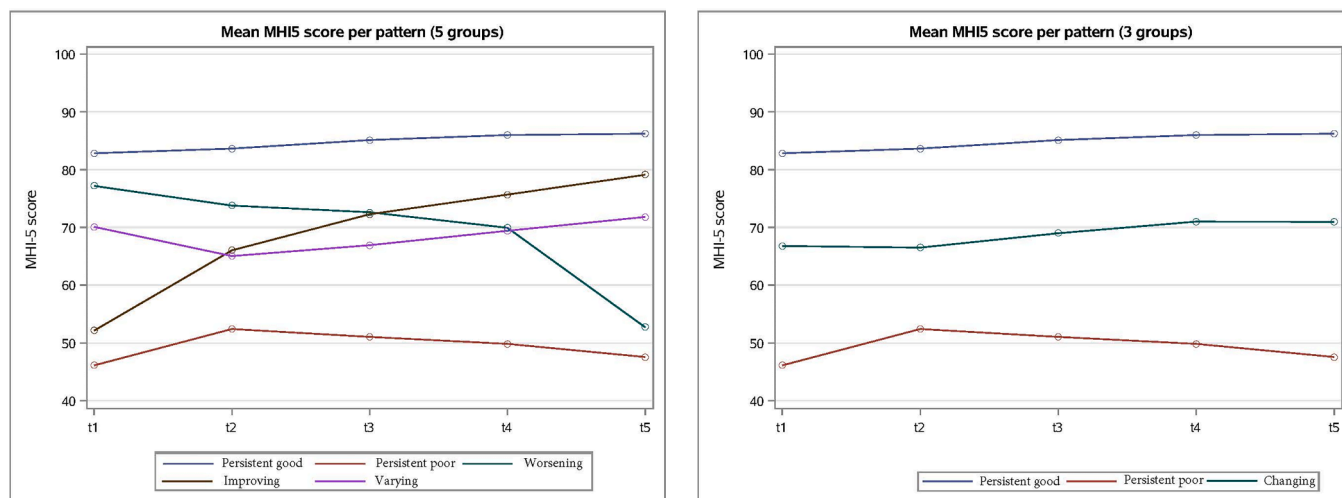


Fig. 2. a/b Mean MHI-5 scores per trajectory in the five rounds: 5 long-term patterns and 3 long-term patterns. Y-axis shows mean MHI-5 score.

Table 3

Associations of baseline (t1) and 20-year follow-up (t5) lifestyle factors with 20-year mental health patterns relative to the persistent good mental health pattern assessed with multivariate models.

	Baseline Round (t1) Persistent Poor Mental Health (OR 95 %CI)	Changing Mental Health	Follow-up Round (t5) Persistent Poor Mental Health (OR 95 %CI)	Changing Mental Health
<b>Age</b>				
(t1:41–55 years)	0.83(0.49–1.39)	0.99(0.81–1.21)	0.85(0.44–1.65)	0.94(0.73–1.21)
(t1:56–70 years)	<b>0.27(0.11–0.69)</b>	<b>0.72(0.53–0.99)</b>	<b>0.23(0.08–0.66)</b>	<b>0.60(0.42–0.88)</b>
<b>Sex</b>				
Female	<b>2.93(1.57–5.47)</b>	<b>1.46(1.20–1.79)</b>	<b>2.61(1.38–4.92)</b>	<b>1.42(1.17–1.74)</b>
<b>Work status</b>				
Unemployed	1.61(0.96–2.71)	<b>1.31(1.06–1.63)</b>	1.12(0.59–2.14)	1.14(0.90–1.46)
<b>Household status</b>				
Not living with a partner	<b>2.64(1.43–4.88)</b>	<b>1.55(1.18–2.05)</b>	<b>2.63(1.55–4.46)</b>	<b>1.88(1.51–2.35)</b>
<b>Education level</b>				
Intermediate education	0.68(0.32–1.43)	0.93(0.73–1.19)	0.71(0.34–1.47)	0.99(0.77–1.27)
Low education	1.39 (0.74–2.62)	1.16(0.93–1.46)	1.18(0.63–2.23)	1.22(0.97–1.54)
<b>Chronic disease</b>				
Chronic disease	2.30(1.39–3.82)	<b>1.57(1.26–1.96)</b>	1.54(0.92–2.56)	<b>1.30(1.07–1.58)</b>
<b>Pain</b>				
Pain scale < 68	<b>3.26(1.91–5.59)</b>	<b>1.84(1.49–2.28)</b>	<b>2.36(1.33–4.19)</b>	<b>1.43(1.16–1.76)</b>
<b>Physical functioning</b>				
Physical scale < 88	1.71(0.99–2.94)	1.20 (0.96–1.49)	<b>3.65(1.94–6.86)</b>	<b>1.38(1.10–1.72)</b>
<b>BMI</b>				
Overweight	0.72(0.44–1.19)	0.98(0.81–1.18)	0.63(0.38–1.06)	0.84(0.69–1.02)
<b>Alcohol consumption</b>				
More than 1 glass	0.89(0.51–1.56)	0.93(0.76–1.14)	0.87(0.48–1.59)	0.99(0.81–1.22)
<b>Smoking</b>				
Smoker	<b>2.10(1.27–3.47)</b>	1.66(1.35–2.03)	<b>2.21(1.12–4.36)</b>	<b>1.82(1.34–2.47)</b>
<b>Physical activity</b>				
Non-conforming to physical activity guidelines	0.92(0.57–1.50)	1.11(0.92–1.33)	1.41(0.85–2.31)	<b>1.36(1.13–1.65)</b>
<b>Sleep</b>				
Fewer than 7 or more than 8 h	<b>2.14(1.28–3.58)</b>	<b>1.44(1.16–1.78)</b>	<b>1.87 (1.13–3.08)</b>	<b>1.23(1.00–1.50)</b>

Separate multivariate models were fitted for variables at the baseline round and at the follow-up round, including all variables. Reference groups were set to: t1:26–40 years & t5:45–60 years; male; employed; living with a partner; high educational level; no chronic diseases; low pain (>=68); low physical limitation (>=88); normal weight (<25 kg/m2); ≤1 alcoholic beverage/day; non-smoker; adherence to guidelines (active for at least 210 min/week); moderate sleep (7–8 h/night); persistent good mental health.

lifestyle factors, changing mental health was positively associated with unhealthy physical activity at final follow-up, but not with BMI or alcohol consumption at baseline or final follow-up. Persistent poor mental health was inversely associated with the 20-year pattern of stable unhealthy BMI, but not with the long-term patterns of physical activity or alcohol consumption.

Our findings on mental health patterns prevalence are similar to some studies and different from others. Our estimates of persistent good (67 %) and persistent poor mental health (3 %) were similar to the Americans Changing Lives Study (persistent good: 68 %, persistent poor:

5 %) and Duke Established Populations for Epidemiologic Studies (persistent good: 77 %, persistent poor: 5 %) (Lincoln & Takeuchi, 2010; Kuchibhatla et al., 2012). Unlike our findings, the Australian Longitudinal Study on Women’s Health found that 55 % (18–23 years old at baseline, 16-year follow-up) had good mental health, 24 % had a varying pattern, and 9 % had poor mental health (Holden, Ware & Lee, 2016). In the Heinz Nixdorf Recall Study, 82 % (45–75 years at baseline, 13-year follow-up) had a good pattern which was higher than in our study (Engel et al., 2020). These differences between our results could be due to differences in study population (e.g., younger (Holden, Ware &

**Table 4**

Associations between long-term lifestyle patterns and long-term mental health patterns relative to the persistent good mental health pattern.

	Univariate Model	Changing Mental Health	*Multivariate Model	Changing Mental Health
	Persistent Poor Mental Health (OR 95 %CI)		Persistent Poor Mental Health (OR 95 %CI)	
<b>BMI</b>				
Stable unhealthy	0.67(0.41–1.16)	1.02(0.82–1.25)	<b>0.50(0.27–0.93)</b>	0.90 (0.70–1.14)
Changing	0.79(0.45–1.38)	<b>1.38(1.11–1.72)</b>	0.61(0.32–1.15)	1.20 (0.94–1.54)
<b>Sleep</b>				
Stable unhealthy	<b>6.85(3.38–13.88)</b>	<b>2.40(1.73–3.33)</b>	<b>5.58(2.48–12.54)</b>	<b>1.80 (1.23–2.64)</b>
Changing	<b>2.68(1.55–4.63)</b>	<b>1.86(1.56–2.23)</b>	<b>2.07(1.14–3.74)</b>	<b>1.54 (1.26–1.88)</b>
<b>Alcohol consumption</b>				
Stable unhealthy	<b>0.47(0.24–0.92)</b>	<b>0.73(0.58–0.92)</b>	0.71(0.33–1.54)	0.78 (0.60 –1.03)
Changing	0.81(0.48–1.37)	0.98(0.80–1.20)	1.05(0.59–1.87)	1.04 (0.83–1.29)
<b>Physical activity</b>				
Stable unhealthy	1.35 (0.61–3.02)	<b>1.72(1.30–2.27)</b>	0.85(0.35–2.07)	1.36 (0.98–1.87)
Changing	1.58(0.94–2.67)	<b>1.42(1.17–1.72)</b>	0.92(0.51–1.66)	1.19 (0.96–1.49)
<b>Smoking</b>				
Stable unhealthy	<b>5.53(3.03–10.10)</b>	<b>2.83(2.11–3.80)</b>	<b>3.35 (1.58–7.11)</b>	<b>2.24 (1.60–3.14)</b>
Changing	<b>2.45(1.44–4.15)</b>	<b>1.79(1.46–2.21)</b>	<b>2.53(1.40–4.57)</b>	<b>1.64 (1.30–2.07)</b>

\*The multivariate model included all long-term patterns of all lifestyle factors and was adjusted for age at final follow-up (t5), sex, household status (t5), chronic disease (t5), and physical functioning (t5). Bold font highlights statistically significant associations ( $p < 0.05$ ). Reference groups are set to: stable healthy BMI (<25 kg/m<sup>2</sup>); stable healthy alcohol consumption ( $\leq 1$  alcoholic beverage/day); stable healthy smoking (non-smoker); stable healthy physical activity (adherence to guidelines: active for at least 210 min/week); stable healthy sleep (7–8 h/night); persistent good mental health.

Lee, 2016) or older (Engel et al., 2020) baseline age) and study design (i. e., slightly short follow-up, use of different mental health assay (e.g., CES-D), use of data-driven instead of pre-defined patterns).

We could not find studies that examined the associations between long-term mental health and the five lifestyle patterns to compare with our study. However, several studies reported associations of lifestyle assessed at one timepoint with long-term mental health outcomes. In line with our results, the Netherlands Mental Health Survey and Incidence Study followed a representative sample of the Dutch population (18–64 years) for three years (Cuijpers & al., 2007). They reported an increased risk for developing a mental health disorder in smokers compared to non-smokers without a mental health disorder at baseline. Furthermore, a systematic review including 14 longitudinal studies on adults aged >50 years, found that suboptimal sleep at baseline and/or follow-up increased the risk of depression in later life (Hill Almeida et al., 2022). In the multivariate model, we found no associations of physical activity and alcohol consumption patterns with mental health patterns. This is not in line with the literature; for example, two meta-analyses of longitudinal studies found physical activity to be protective and alcohol consumption to be a risk factor for good mental health (Pearce et al., 2022; Zimmermann et al., 2020). However, these were pooled analyses from several studies with large heterogeneities reported. The studies in these reviews are also different in their population, design, and analyses. Furthermore, none adjusted for the same lifestyle factors/patterns or assessed long-term mental health patterns as an outcome (Pearce et al., 2022; Zimmermann et al., 2020). For BMI, a meta-analysis of fifteen longitudinal studies showed bidirectional associations between obesity and depression onset (Luppino et al., 2010). Unlike our study, the studies in this review did not explore long-term patterns of either BMI or mental health. Furthermore, the pooled analyses highlighted stronger associations in Americans than in Europeans, pointing to other sociocultural factors that might be playing a role. Additionally, the associations were found mainly with obesity and not overweight, whereas in our study overweight and obesity were included together as unhealthy BMI.

Our findings on the long-term associations of poor/changing mental health with unhealthy/changing sleep and smoking emphasize that unhealthy behaviour starting in young adulthood can persist into older age, negatively affecting mental health. The findings reflect dynamic and interrelated patterns making it difficult to establish a clear directionality for cause and effect between behaviour and mental health. Despite the longitudinal nature of the study, more controlled

experimental design would be needed to show whether unhealthy lifestyle causes poor mental health or vice versa. A recent systematic review of sixteen studies for example, found bidirectional associations between anxiety/depression at baseline and later smoking onset, and between baseline smoking and later anxiety/depression onset (Fluharty et al., 2017). This underlying complexity could be attributed to neurobiological mechanisms linking lifestyle factors to the brain's reward system and mental health (Chellappa & Aeschbach, 2022; Le Foll et al., 2022). Sleep regulates neuro-molecular pathways for emotions through the production of neurotransmitters such as dopamine and serotonin, which in turn regulate mood, and these neurotransmitters are also impacted by smoking (Chellappa & Aeschbach, 2022; Le Foll et al., 2022). Furthermore, exposure to adversity in young age can alter neuro-cognitive development pathways that are linked to unhealthy behaviour for smoking and alcohol intake (Duffy, McLaughlin & Green, 2018).

The main strength of our study is the 20-year follow-up during adulthood and the broad sociodemographic, health, and lifestyle data available. Thus, we were able to describe long-term patterns and explore associations, which to the best of our knowledge, has not been done before for lifestyle and mental health combined. However, our study also has limitations. The MHI-5 provides a limited view of the landscape of mental health and does not reflect the dynamic and complex changes in mental health over a long period of time. Furthermore, five years can be considered a long time to depict shorter variations in lifestyle and mental health that might occur within this timeframe. However, this analysis is based on a rolling cohort study for 30 years and that has been designed with follow-up rounds every five years. It is thus not possible to have more frequent follow ups within the frame of this study. Additionally, the MHI-5 cut-off was chosen based on validation in a Dutch representative sample, but it remains unclear if it adequately reflects clinical levels of psychological distress (Perenboom et al., 2000). The mental health of some participants may have been misclassified, especially for those close to the cut-off, or if changes in mental health may have occurred before/after the study or between follow-ups. Additionally, our sample had insufficient power to explore all five lifestyle patterns and mental health. For simplicity, we also combined the changing patterns. Finally, long-running cohort studies usually represent a healthier population, also reflected in our study population who less often had poor mental health at baseline than excluded participants (results not shown) and had healthier habits such as for smoking compared to the general Dutch population. This might have led to an overestimation of the persistent good mental health pattern prevalence.

However, this “healthy-user bias” is unlikely to have affected our findings as we did not find associations of persistent good mental health with healthy patterns for three of the five lifestyle factors. We tried to account for all potential confounding factors, but we cannot eliminate the risk of residual confounding.

Our findings have several implications for research and interventions. Long-term mental health patterns in relation to lifestyle have not been studied before and warrant further research, including with longer and more frequent follow-ups to better understand mental health dynamics. Future research should also include larger representative samples of the Dutch and other ethnic populations to broaden the understanding of lifestyle in mental health as people age. By clarifying the directionality of associations and accounting for the complex mechanisms that govern them, interventions can be better tailored to improve health behaviour and mental health, whilst strengthening the resilience capacities of people to face life’s challenges.

Our study shows that long-term good and changing mental health are more common than poor mental health in Dutch adults. We found that poor and changing mental health are affected by unhealthy habits for smoking and sleep over 20 years. The associations between mental health and lifestyle require further research to better understand directionality and the potential mechanisms involved. This would feed into interventions tailored towards improving lifestyle and mental health, that may positively affect health and quality of life over time.

#### Authors’ contributors

Menassa M wrote the paper and participated in the analysis plan of the study. KEJ Wesenhagen conducted the analysis and participated in the revision and editing of the paper. Stronks participated in the revision and editing of the paper. Franco OH participated in the revision and editing of the paper. WMM Verschuren conceptualized and designed the study and participated in the revision and editing of the paper. HSJ Picavet conceptualized and designed the study and participated in the analysis plan, revision, and editing of the paper. All authors saw and approved the final version and no other person made a substantial contribution to the paper.

#### Data sharing statement

The data on this study are derived from a long-running cohort study, the Doetinchem Cohort Study. The informed consent provided by the study participants limits the use of the data for specific purposes only. For the purpose of verification/validation/replication/meta-analyses, external researchers can contact Doetinchemstudie@rivm.nl.

#### CRedit authorship contribution statement

**M Menassa:** Writing – original draft, Methodology. **KEJ Wesenhagen:** Writing – review & editing, Methodology, Formal analysis. **K Stronks:** Writing – review & editing. **OH Franco:** Writing – review & editing. **WMM Verschuren:** Writing – review & editing, Conceptualization. **HSJ Picavet:** Writing – review & editing, Supervision, Methodology, Conceptualization.

#### Declaration of Competing Interest

None. The authors Menassa M, KEJ Wesenhagen, Stronks K, Franco OH, WMM Verschuren, and HSJ Picavet declare no competing interest.

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#### Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.archger.2023.105222.

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