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Maastricht University

Faculty of Medicine and Life Sciences
School for Life Sciences
Master of Biomedical Sciences

Master's thesis

A healthy lifestyle is positively associated with mental and cardiovascular health

Margot Debay

Thesis presented in fulfillment of the requirements for the degree of Master of Biomedical Sciences, specialization Molecular Mechanisms in Health and Disease

SUPERVISOR :

dr. Nelly SAENEN

MENTOR :

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A healthy lifestyle is positively associated with mental and cardiovascular health*

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*Running title: *Lifestyle, mental, and cardiovascular health*

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ABSTRACT

Health behaviours, including BMI, physical activity, smoking status, alcohol consumption, and diet, have been associated with mental and cardiovascular health. However, most studies investigate a single behaviour. In this study, we developed a lifestyle score combining these health behaviours. The association between this score and multiple mental and cardiovascular health outcomes was determined using Belgian Health Interview Survey 2018 (BHIS) data (n=5,997). Additionally, in a subset of 888 participants, blood pressure (BP) measurements were linked to lifestyle. Multivariate logistic regressions and mixed-effect models were carried out, taking into account *a priori* selected covariates. The healthiest lifestyle score was achieved by 14.5% of the participants. Compared to the least healthy lifestyle, the healthiest lifestyle was associated with lower odds of psychological distress (odds ratio [OR]: 0.41; 95% confidence interval [CI]: 0.30 to 0.56) and cardiovascular disease (OR: 0.25; 95% CI: 0.12 to 0.52). Similar results were found for low life satisfaction, suboptimal vital energy, major depressive disorder, generalised anxiety disorder, suicidal ideation, high self-reported BP, high blood cholesterol, and high or potentially high BP. Finally, the healthiest lifestyle was associated with higher odds of normal BP, represented by 3.84% (95% CI: -6.88 to -0.69%) lower systolic and 6.16% (95% CI: -9.25 to -2.96%) lower diastolic BP compared to the least healthy lifestyle. These results indicate that a healthy lifestyle is associated with lower odds of impaired mental and cardiovascular health in the Belgian population, suggesting that stronger adherence to lifestyle guidelines could reduce disease prevalence, hospitalisation, and healthcare costs.

INTRODUCTION

Public health authorities emphasise the importance of a healthy lifestyle to prevent chronic diseases [1]. However, despite the promotion of good health behaviours, many Belgians still live an unhealthy lifestyle [2]. Almost half of the adult population is overweight (49%). The average Belgian sits for 6 hours per day and does not spend sufficient time on physical activity. Only 38% of the Belgian population older than 6 reaches the recommended daily vegetable intake, and 38% eats sweet or salty snacks on a daily basis. Furthermore, 77% drinks alcohol, and 10% does so daily. Moreover, approximately 15% of the Belgian population smokes daily [2].

These unhealthy behaviours increase the risk of both mental and physical health diseases [3, 4]. Studies have shown that being underweight or obese is associated with higher odds of depression [5]. In addition, obesity also increases the risk of type-2 diabetes, hypertension, myocardial infarction, and certain cancers [6]. Furthermore, the increased risk of lung and cardiovascular diseases due to smoking is well documented, and in the last years, smoking has also been associated with mental health disorders such as depressive disorder [7, 8]. In contrast, regular physical activity has been shown to prevent the development of diabetes, cancer and osteoporosis [9]. Additionally, intervention

studies have shown that increasing physical activity is also an effective treatment for reducing symptoms of depressive and anxiety disorders [10, 11]. Another critical protective factor for cardiovascular and mental health is a healthy diet. Studies have shown that an unhealthy diet is associated with a higher risk of heart diseases and metabolic disorders, but also kidney stones and stroke, and that improving one's diet decreases disease risk factors [12-15]. Other studies have also highlighted the importance of a healthy diet for good mental health [16, 17]. Moreover, chronic alcohol consumption increases the risk of colon and stomach cancer, and binge drinking can even cause sudden cardiac death [18, 19]. Additionally, excessive alcohol consumption has been linked to a higher likelihood of developing depressive- and anxiety-like symptoms [20].

Even though multiple studies evaluated these individual health behaviours, the field still lacks research concerning a combination of health behaviours in relation to mental and cardiovascular health. Research has shown that unhealthy lifestyle behaviours often co-occur, cluster together, and exert a synergistic effect on each other [21]. Thus, assessing healthy lifestyle behaviours in combination with each other rather than independently better reflects the real-life association between lifestyle and physical and mental health. Therefore, it is essential to study a combination of health behaviours to supplement the already known information and accurately portray how lifestyle, cardiovascular health, and mental health are connected [21, 22].

This study aims to combine the health behaviours BMI, physical activity, smoking status, alcohol consumption, and diet into a categorical healthy lifestyle score to evaluate its association with mental and cardiovascular health. First, this healthy lifestyle score is created and then validated as a predictor for good subjective health. Next, the associations between the score and mental and cardiovascular health are determined. More specifically, the mental health indicators investigated for their association with lifestyle are psychological distress, low life satisfaction, suboptimal vital energy, major depressive disorder, generalised anxiety disorder, and suicidal ideation. The cardiovascular indicators included in this study are cardiovascular disease in the past 12 months, self-reported high blood pressure (BP), self-reported high blood cholesterol, and objective measurements of high or potentially high BP, systolic and diastolic BP. We hypothesise that a higher healthy lifestyle score is associated with lower odds of impaired mental and cardiovascular health.

METHODS

Study design and population – This cross-sectional study was conducted using Belgian Health Interview Survey 2018 (BHIS) data. The BHIS is a nationwide survey used to describe the health status of the Belgian population and its determinants. Participants of the BHIS were selected using the Belgian national register as the sampling frame according to a multistage sampling design. This design involves geographical stratification according to region (Flanders, Brussels, Wallonia) and provinces. Next, a cluster of 50 individuals was selected within each stratum. A selection of households was then made in each cluster, followed by a selection of participants within the households.

Data collection was done through a questionnaire administered as a face-to-face interview and a paper questionnaire handed out for self-completion, which 11,611 participants completed. The study population was limited to participants aged 18 years or older, providing information regarding their lifestyle, background, mental health and cardiovascular health (Fig. 1). The final BHIS sample used in this study included 5,997 participants.

In addition, a subset of 1,184 BHIS-participants took part in the Belgian Health Examination Survey 2018 (BELHES). The examination included a questionnaire, a physical exam, and a blood and urine sample collection. Following exclusion of participants with missing data, the final BELHES sample size for this study included 888 participants (Fig. 1).

Mental health – Several indicators of mental health were determined in the BHIS. Psychological distress was assessed using the General Health Questionnaire (GHQ-12) [23]. Participants were classified as having psychological distress if they exhibited at least two symptoms (GHQ-12 score: 2) of feeling psychologically unwell. Life satisfaction was measured using the Cantril scale, ranging from 0 to 10. A score of up to 5 was used to indicate low life satisfaction [24]. Suboptimal vital energy was determined when a person scored equal to or below the average score plus standard deviation (SD) on the Short Form Health Survey (SF-36) [25]. Major depressive disorder was defined using the criteria of the Patient Health

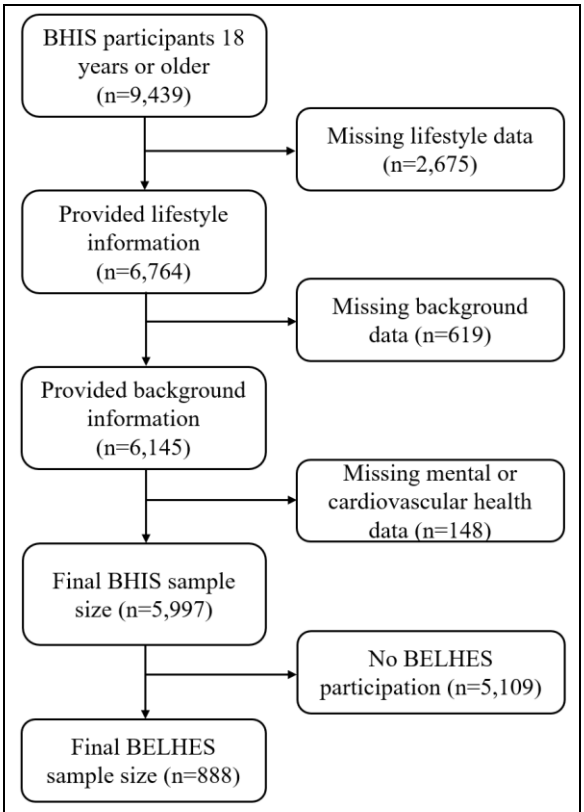

Fig. 1 – Flow diagram of participant inclusion and exclusion.

Questionnaire (PHQ-9), in which a participant is classified as having major depressive syndrome if five or more of the criteria were present at least more than half the days in the past two weeks, and if one of the symptoms was depressed mood or anhedonia [26]. The Generalised Anxiety Disorder (GAD-7) questionnaire was used to determine the presence of generalised anxiety disorder. Participants with a score of 10 or more were classified as having generalised anxiety disorder [27]. Finally, a dichotomous question was asked regarding suicidal ideation in the 12 months prior to the interview.

Cardiovascular health – Six cardiovascular health indicators were used in this study. In the BHIS, having had any cardiovascular disease (myocardial infarction, coronary heart disease, or other serious heart disease), self-reported high BP, and self-reported high cholesterol level in the blood, all in the past year, were assessed by dichotomous questions. From the BELHES, the average BP of two measurements was used to determine whether participants experienced high or potentially high BP (systolic BP > 140 mmHg, diastolic BP > 90 mmHg, or medication use for hypertension). In addition, from the BELHES, the average systolic and diastolic BP were determined from two measurements.

Healthy lifestyle score – We developed a healthy lifestyle score based on five health behaviours (Table 1). BMI was calculated as weight divided by height in meters squared (kg/m^2), based on the participants' self-reported height and weight at the time of the interview. BMI was classified into four categories: underweight (BMI <18.5 kg/m^2), normal weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2) and obese (BMI > 30.0 kg/m^2). Due to a U-shaped association between BMI and mental health, with obese and underweight participants experiencing the most mental wellbeing issues, obesity and underweight were classified as the least healthy. BMI was scored as: obese or underweight (0); overweight (1); and normal weight (2) [5].

Physical activity was assessed by the question "What describes best your leisure time activities during the last year?". Four categories were made and scored as: sedentary activities (0); light activities less than 4 hours/week (1); light activities 4 hours/week or more, or recreational sport less than 4 hours/week (2); and recreational sport 4 hours/week or more, or intense training (3).

Smoking status was divided into and scored as four categories. Participants were categorised as regular smokers if they smoked daily, smoked 4 to 6 days/week, or quit smoking less than one month before participating in the study (0). Occasional smokers were defined as smoking more than once per month to smoking 3 days/week (1). Participants were classified as former smokers if they quit smoking at least one month before the interview or smoked less than once per month (2). The final category consisted of people who never smoked (3).

The number of alcoholic drinks consumed per week was used to categorise alcohol consumption. The different categories were: 22 drinks/week or more (0); 15–21 drinks/week (1); 8–14 drinks/week (2); 1–7 drinks/week (3); less than 1 drink/week or abstainers (4).

In line with an article by Benetou et al., a diet score was calculated using the frequency of eating fruit, vegetables, snacks, and sodas, based on the question "How often do you eat said food group?" [28]. For fruit, as well as vegetable consumption, the frequency of consumption was scored as: never (0); <1x/week (1); 1–3x/week (2);

Table 1 – **Healthy lifestyle score.** Each behaviour is scored from least healthy to healthiest, receiving an absolute score dependent on the number of categories. A relative score is then calculated (0–1) to achieve equal weight of the health behaviours. This score is summed to obtain the final healthy lifestyle score.

Indicator	Least healthy → Healthiest					Range abs. score	Range rel. score
BMI	Underweight Obese		Overweight		Normal weight	0-2	0-1
Physical activity	Sedentary activities	Light activities <4 hrs/week		Light activities ≥4 hrs/week or recreational sport <4 hrs/week	Recreational sport ≥4 hrs/week or intense training	0-3	0-1
Smoking status	Regular smokers	Occasional smokers		Former smokers	Non-smokers	0-3	0-1
Alcohol consumption	≥22 drinks/week	15–21 drinks/week	8–14 drinks/week	1–7 drinks/week	<1 drink/week or abstainers	0-4	0-1
Diet	Diet score 0–9		Diet score 10–12		Diet score 13–16	0-2	0-1
							0-5

4–6x/week (3); and ≥1x/day (4). The frequencies of eating snacks and drinking sodas were scored as: never (4); <1x/week (3); 1–3x/week (2); 4–6x/week (1); and ≥1x/day (0). The total diet score ranged from 0 to 16, with a maximum of 4 points scored for each diet parameter. A diet score of 0–9 points was classified as the least healthy behaviour (0), a score of 10–12 made up the middle category (1), and a score of 13–16 was classified as the healthiest diet (2) [28].

All five health behaviours described above were combined into one healthy lifestyle score (Table 1). To calculate the total score, each health behaviour was given equal weight by recalculating the maximum absolute score to a relative score of 1. The relative scores were then summed to achieve a final healthy lifestyle score ranging from 0 to 5, from least healthy to healthiest. This final score was categorised as 0–1 (0); >1–2 (1); >2–3 (2); >3–4 (3); >4–5 (4). Due to the small sample size of category 0 (n=129), this category was combined with category 1, consistent with other studies [29].

Validation – The healthy lifestyle score was validated by creating a receiver operating characteristic (ROC) curve and calculating the area under the curve (AUC) of the adjusted association between the lifestyle score and good subjective health. Subjective health was determined based on the question: "How is your health in general? Is it…" with answer categories: very good; good; fair; bad; very bad. The answers "very good" and "good" were used to define good subjective health.

Statistical analysis – All statistical analyses were performed in SAS 9.3 (SAS Institute Inc., Cary, NC, USA). For all variables except diastolic and systolic BP, multivariate logistic regressions were adjusted for *a priori* selected covariates, including age (continuous), gender (male; female), highest educational level of the household (up to lower secondary education; higher secondary education; higher education), region (Flanders; Brussels; Wallonia), and nationality (Belgian; non-Belgian (EU); non-EU). Regressions regarding mental health indicators were additionally adjusted for perceived social support (poor; intermediate; strong), which was determined based on the OSLO scale [30]. We adjusted for the study design by including strata and clusters in the model. By using sampling weights, we were able to extrapolate the results to the Belgian population. Results are presented as the odds ratios (OR), with 95% confidence interval (CI) and *p*-values, of having poor mental health compared to the lowest healthy lifestyle score.

The BELHES variables diastolic and systolic BP were log(10) transformed to better approximate a normal distribution. To assess the associations between the healthy lifestyle score and diastolic and systolic BP, mixed-effect models (unstructured covariance matrix) were developed with household number as random effect, adjusted for the abovementioned *a priori* selected covariates. Results are presented as the percentage difference in diastolic or systolic BP, with 95% CI and *p*-values, compared to the lowest healthy lifestyle score.

RESULTS

Study population characteristics – Table 2 shows the descriptive characteristics of the study population (n=5997). The BHIS study population consisted for 48.8% of male participants and reported an average age of 50.0 ± 17.5 years. In addition, for 53.3% of the participants, the highest diploma in the household was that of higher education. The results also showed that 41.1% of the participants lived in the Flanders, 23.1% in Brussels, and 35.7% in Wallonia. Furthermore, the study population consisted for 86.6% of participants of Belgian nationality. Finally, 49.4% of the study population rated their perceived social support as intermediate, and 15.7% as high. The general characteristics of the BELHES subset were comparable to those of the BHIS population, with slightly more participants with higher education as the highest educational level in the household (59.6%) and more participants from Flanders (48.1%). The extrapolated population characteristics, taking weight, strata and clusters of the study set-up into account, were comparable to those of the BHIS study population, with the exception of region (59.0% participants from Flanders) (Supplementary Table 1). Furthermore, the adjusted estimated effects of the covariates in the model of the lifestyle score and mental or cardiovascular health are shown from Supplementary Table 2 to 13.

Health behaviours – Of the study population, 15.9% was obese, 29.7% mostly performed sedentary activities in their leisure time, and 16.6% were regular smokers (Table 2). In addition, drinking 22 drinks per week or more was reported by 4.9% of the study population, and an unhealthy diet with a score between 0 and 9 was calculated for 29.2% of the population. Moreover, 14.1% of the population scored 1 point on the healthy lifestyle score, 32.0% scored 2 points, 39.3% scored 3 points, and 14.5% achieved the maximum healthy lifestyle score of 4 points. Comparable results were found in the BELHES population, with slightly fewer participants who mostly perform sedentary activities (26.8%) and fewer participants who drink less than one drink per week or are abstainers (44.7%). Furthermore, the BHIS study population's health behaviours are representative of the extrapolated population (Supplementary Table 1).

Prevalence of mental and cardiovascular health outcomes – Table 3 shows the study population's mental and cardiovascular health characteristics. For mental health, the highest prevalence was found for suboptimal vital energy (86.6%). Furthermore, 32.2% of the study population suffered from psychological distress, and 11.9% from low life satisfaction. In addition, 4.7% of the population was classified as having major depressive disorder, and 10.9% suffered from generalised anxiety disorder. Furthermore, 4.4% of the population had experienced suicidal thoughts in the past 12 months.

Of the 5,997 BHIS participants, 4.4% had experienced cardiovascular disease in the last year, 18.1% had reported high blood pressure, and 18.6% had reported having a high blood cholesterol level. In the subset of 888 BELHES participants, 30.3% had a measured high or potentially high BP. The average systolic BP was 120.2 ± 18.5 mmHg, and the average diastolic BP was 77.5 ± 10.6 mmHg.

Model validity – A ROC curve was made to validate the healthy lifestyle score adjusted for all covariates (Fig. 2). The ROC curve shows an AUC of 0.7581, indicating a 75.8% predictive accuracy for the adjusted healthy lifestyle score as a predictor for good subjective health.

Associations between healthy lifestyle and mental health – A higher healthy lifestyle score (i.e. living healthier) was associated with lower OR for having psychological distress, low life satisfaction, suboptimal vital energy, major depressive disorder, generalised anxiety disorder, and suicidal ideation (Table 4).

More specifically, a healthy lifestyle score of 2 was associated with lower odds of psychological distress of 0.69 (95% CI: 0.54 to 0.88) compared to the least healthy group. A healthy lifestyle score of 3 was associated with lower odds of psychological distress of 0.51 (95% CI: 0.40 to 0.64), and scoring 4 was associated with lower odds of psychological distress of 0.41 (95% CI: 0.30 to 0.56) compared to the least healthy group.

In addition, having a healthy lifestyle score of 2, 3 and 4 compared to 1 was associated with lower odds of low life satisfaction of 0.67 (95% CI: 0.49 to 0.91), 0.38 (95% CI: 0.27 to 0.54), and 0.22 (95% CI: 0.13 to 0.36), respectively.

Table 2 – General characteristics and health behaviour characteristics of BHIS (n=5997) and BELHES (n=888) population.

Variable		N (%) or Mean ± SD	
General characteristics		**BHIS**	**BELHES**
Age, years		50.0 ± 17.5	48.8 ± 16.1
Gender	Male	2924 (48.8)	425 (47.9)
Highest educational level of the household	Up to lower secondary education	1004 (16.7)	116 (13.1)
	Higher secondary education	1795 (29.9)	243 (27.4)
	Higher education	3198 (53.3)	529 (59.6)
Region	Flanders	2467 (41.1)	427 (48.1)
	Brussels	1387 (23.1)	197 (22.2)
	Wallonia	2143 (35.7)	264 (29.7)
Nationality	Belgian	5196 (86.6)	766 (86.3)
	Non-Belgian (EU)	561 (9.4)	83 (9.4)
	Non-EU	240 (4.0)	39 (4.4)
Perceived social support	Poor	944 (15.7)	153 (17.2)
	Intermediate	2964 (49.4)	455 (51.2)
	Strong	2089 (34.8)	280 (31.5)
Health behaviours			
BMI	Underweight	164 (2.7)	22 (2.5)
	Normal weight	2828 (47.2)	429 (48.3)
	Overweight	2054 (34.3)	307 (34.6)
	Obese	951 (15.9)	130 (14.6)
Physical activity	Sedentary activities	1778 (29.7)	238 (26.8)
	Light activities <4 h/w	1377 (23.0)	195 (22.0)
	Light activities ≥4 h/w or recreational sport <4 h/w	1800 (30.0)	278 (31.3)
	Recreational sport ≥4 h/w or intense training	1042 (17.4)	177 (19.9)
Smoking status	Regular smokers	995 (16.6)	156 (17.6)
	Occasional smokers	158 (2.6)	31 (3.5)
	Former smokers	1454 (24.3)	202 (22.8)
	Non-smokers	3390 (56.5)	499 (56.2)
Alcohol consumption	<1 drink/week or abstainers	2898 (48.3)	397 (44.7)
	1–7 drinks/week	1761 (29.4)	275 (31.0)
	8–14 drinks/week	726 (12.1)	115 (13.0)
	15–21 drinks/week	320 (5.3)	57 (6.4)
	≥22 drinks/week	292 (4.9)	44 (5.0)
Diet	Diet score 0–9	1749 (29.2)	253 (28.5)
	Diet score 10–12	2599 (43.3)	393 (44.3)
	Diet score 13–16	1649 (27.5)	242 (27.3)
Healthy lifestyle score	1	847 (14.1)	122 (13.7)
	2	1921 (32.0)	273 (30.7)
	3	2358 (39.3)	365 (41.1)
	4	871 (14.5)	128 (14.4)

h/w: hours per week; BHIS: Belgian Health Interview Survey; BELHES: Belgian Health Examination Survey.

Table 3 – Prevalence of mental and cardiovascular health outcomes (n=5997).

Outcome variables	N (%) or mean ± SD
Mental health	
Psychological distress	1930 (32.2)
Low life satisfaction	716 (11.9)
Suboptimal vital energy	5192 (86.6)
Major depressive disorder	282 (4.7)
Generalised anxiety disorder	653 (10.9)
Suicidal ideation	266 (4.4)
Cardiovascular health	
Cardiovascular disease	263 (4.4)
Self-reported high BP	1083 (18.1)
High blood cholesterol	1115 (18.6)
High or potentially high BP[a]	269 (30.3)
Systolic BP (mmHg)[a]	120.2 ± 18.5
Diastolic BP (mmHg)[a]	77.5 ± 10.6

[a]BELHES subset (n=888)

Furthermore, a healthy lifestyle score of 3 and 4 was associated with lower odds of suboptimal vital energy levels of 0.52 (95% CI: 0.36 to 0.74) and 0.30 (95% CI: 0.20 to 0.45) compared to the least healthy group, respectively. No association was found for group 2.

A healthy lifestyle score of 2 and 3, compared to the least healthy group of 1, was associated with lower odds of major depressive disorder of 0.38 (95% CI: 0.25 to 0.60) and 0.20 (95% CI: 0.12 to 0.35), respectively. Most notably, a healthy lifestyle score of 4 was associated with lower odds of 0.06 (95% CI: 0.03 to 0.13) of major depressive disorder compared to the least healthy group.

In addition, a higher healthy lifestyle score was associated with significantly lower odds ratios for generalised anxiety disorder. A healthy lifestyle score of 2, 3 and 4, compared to a score of 1, was associated with lower odds of 0.63 (95% CI: 0.46 to 0.86), 0.39 (95% CI: 0.28 to 0.56), and 0.19 (95% CI: 0.11 to 0.33), respectively.

Finally, a healthy lifestyle score of 3 and 4, compared to 1, was associated with significantly lower odds of suicidal ideation of 0.56 (95% CI: 0.34 to 0.92) and 0.24 (95% CI: 0.12 to 0.47), respectively. Group 2 did not significantly differ from group 1 regarding suicidal ideation.

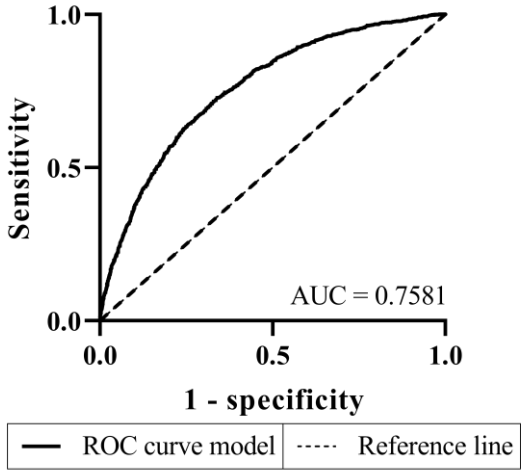

Fig. 2 – Validation of the healthy lifestyle score. Receiver operating characteristic (ROC) curve for adjusted healthy lifestyle model as a predictor for good subjective health.

Associations between healthy lifestyle and cardiovascular health – A higher healthy lifestyle score (i.e. living healthier) was associated with lower OR of cardiovascular disease, self-reported high BP, self-reported high blood cholesterol, and high or potentially high BP (Table 5).

More specifically, compared to the least healthy group with a score of 1, a healthy lifestyle score of 3 and 4 was associated with lower odds of cardiovascular disease of 0.59 (95% CI: 0.37 to 0.97) and 0.25 (95% CI: 0.12 to 0.52), respectively. Group 2 did not significantly differ from group 1.

Furthermore, a healthy lifestyle score of 2, 3 and 4, compared to a score of 1, was associated with significantly lower odds of self-reported high BP of 0.74 (95% CI: 0.56 to 0.98), 0.48 (95% CI: 0.36 to 0.64), and 0.27 (95% CI: 0.18 to 0.41), respectively.

Additionally, a healthy lifestyle score of 2, 3 and 4 was associated with significantly lower odds of high self-reported blood cholesterol of 0.68 (95% CI: 0.52 to 0.90), 0.52 (95% CI: 0.40 to 0.68) and 0.32 (95% CI: 0.22 to 0.46) compared to the least healthy group, respectively.

Compared to the least healthy group, participants with a score of 3 and 4 had significantly lower odds of 0.39 (95% CI: 0.22 to 0.71) and 0.28 (95% CI: 0.13 to 0.64) of having high or potentially high blood pressure. Group 2 did not significantly differ from group 1.

Finally, in the BELHES population, a higher healthy lifestyle score was associated with

Table 4 – Odds ratios (OR) of the associations between the healthy lifestyle score and mental health outcomes (with 95% confidence interval [CI] and *p*-values). Analyses were adjusted for age, gender, highest educational level of the household, nationality, and perceived social support.

Lifestyle score	OR	95% Cl	*p*-value
	Psychological distress		
1	Ref		
2	0.69	0.54 – 0.88	0.003
3	0.51	0.40 – 0.64	< 0.001
4	0.41	0.30 – 0.56	< 0.001
	Low life satisfaction		
1	Ref		
2	0.67	0.49 – 0.91	0.011
3	0.38	0.27 – 0.54	< 0.001
4	0.22	0.13 – 0.36	< 0.001
	Suboptimal vital energy		
1	Ref		
2	0.77	0.53 – 1.12	0.174
3	0.52	0.36 – 0.74	< 0.001
4	0.30	0.20 – 0.45	< 0.001
	Major depressive disorder		
1	Ref		
2	0.38	0.25 – 0.60	< 0.001
3	0.20	0.12 – 0.35	< 0.001
4	0.06	0.03 – 0.13	< 0.001
	Generalised anxiety disorder		
1	Ref		
2	0.63	0.46 – 0.86	0.003
3	0.39	0.28 – 0.56	< 0.001
4	0.19	0.11 – 0.33	< 0.001
	Suicidal ideation		
1	Ref		
2	0.68	0.42 – 1.09	0.107
3	0.56	0.34 – 0.92	0.023
4	0.24	0.12 – 0.47	< 0.001

significantly lower systolic and diastolic blood pressure measurements (Table 6). A healthy lifestyle score of 4 was associated with 3.84% (95% CI: -6.88 to -0.69) lower systolic BP compared to a score of 1. Groups 2 and 3 did not significantly differ. Furthermore, a healthy lifestyle score of 2, 3 and 4, compared to 1, was associated with a lower diastolic BP of 3.04% (95% CI: -5.69 to -0.31), 4.65% (95% CI: -7.23 to -2.01), and 6.16% (95% CI: -9.25 to -2.96), respectively.

Table 5 – Odds ratios (OR) of the associations between the healthy lifestyle score and cardiovascular health outcomes (with 95% confidence interval [CI] and *p*-values). Analyses were adjusted for age, gender, highest educational level of the household, and nationality.

Lifestyle score	OR	95% Cl	*p*-value
	Cardiovascular disease		
1	Ref		
2	0.63	0.39 – 1.02	0.060
3	0.59	0.37 – 0.97	0.035
4	0.25	0.12 – 0.52	< 0.001
	Self-reported high BP		
1	Ref		
2	0.74	0.56 – 0.98	0.033
3	0.48	0.36 – 0.64	< 0.001
4	0.27	0.18 – 0.41	< 0.001
	High blood cholesterol		
1	Ref		
2	0.68	0.52 – 0.90	0.006
3	0.52	0.40 – 0.68	< 0.001
4	0.32	0.22 – 0.46	< 0.001
	High or potentially high BP[a]		
1	Ref		
2	0.82	0.45 – 1.49	0.507
3	0.39	0.22 – 0.71	0.002
4	0.28	0.13 – 0.64	0.003

[a]BELHES subset (n=888)

DISCUSSION

This study showed that a healthy lifestyle, consisting of a healthy BMI, regular sport, non-smoking, low alcohol consumption, and a healthy diet, is positively associated with mental and cardiovascular health. According to the World Health Organisation (WHO), in 2019, approximately 10% and 14% of disability-adjusted life years (DALYs) in Belgium were caused by mental and substance use disorders, and cardiovascular diseases, respectively [31]. Our findings emphasise the need to continue promoting a healthy lifestyle to benefit Belgians' mental and cardiovascular health and decrease this considerable disease burden.

Other studies – We found that only 14.5% of participants scored a maximum healthy lifestyle score of 4. These results are largely consistent with other research reporting a minority of adults exhibiting multiple healthy behaviours, despite different scoring methods [32, 33].

Table 6 – Difference (%) in average systolic and diastolic blood pressure in association with the healthy lifestyle score (with 95% confidence interval [CI] and *p*-values). Analyses were performed in the BELHES subset (n=888) and adjusted for age, gender, highest education of the household, and nationality.

Lifestyle score	% difference	95% CI	*p*-value
	Systolic BP		
1	Ref		
2	-0.66	-3.28 – 2.02	0.624
3	-1.36	-3.92 – 1.27	0.307
4	-3.84	-6.88 – -0.69	0.018
	Diastolic BP		
1	Ref		
2	-3.04	-5.69 – -0.31	0.030
3	-4.65	-7.23 – -2.01	< 0.001
4	-6.16	-9.25 – -2.96	< 0.001

Furthermore, we found a positive association between the healthy lifestyle score and better mental and cardiovascular health outcomes. As expected, these results are comparable to the findings of other studies associating a healthier lifestyle to better mental [3, 29, 34] and cardiovascular health [35-38].

More specifically, we found that scores of 3 and 4 were associated with significantly lower odds of all mental health and most cardiovascular health outcomes compared to the lowest healthy lifestyle score. Additionally, we observed a trend of decreasing odds of impaired mental and cardiovascular health with each point scored for a healthy lifestyle. In accordance with previous studies, this trend suggests a dose-response relationship [29].

However, we found stronger effects than some other studies [29, 35, 38-41]. For example, a study performed in Germany by Buttery *et al*. (2014) assessed the relationship between combined dichotomised health behaviours and mental health [29]. This study found an OR of 0.76 (95% CI: 0.61 to 0.95) of having depression, for women adopting four or five healthy behaviours, compared to those adopting none or one healthy behaviour [29]. Regarding cardiovascular health, a meta-analysis found a 0.37 relative risk (RR) (95% CI: 0.31 to 0.43) of cardiovascular disease for participants with the most healthy lifestyle habits compared to those with the least healthy lifestyle habits [37]. Both these studies found weaker associations compared to our findings. Similar results were found in other studies that dichotomised health behaviours in their lifestyle score [29, 38-40]. These differences in the strength of associations could be due to the method of scoring lifestyle, as dichotomisation leads to oversimplification of the health behaviours [42]. Consequently, this scoring method may lead to a loss of detail that can be avoided when using a range from least healthy to healthiest behaviours to distinguish differences in lifestyle, as was done in our study.

Finally, in a subset, a healthy lifestyle score of 4, compared to a score of 1, was associated with lower systolic and diastolic BP of 3.84% (95% CI: -6.88 to -0.69) and 6.16% (95% CI: -9.25 to -2.96), respectively. Assuming a high BP of 140/90 mmHg, a healthy lifestyle score of 4 is thus associated with a lower BP of approximately 5.4/5.5 mmHg compared to a score of 1. These results support previous interventional research implementing lifestyle changes to reduce BP [43]. A meta-analysis of 93 randomised controlled trials showed that endurance training reduces blood pressure by 3.5/2.5 mmHg [44]. In addition, a healthy weight, regular exercise, smoking cessation, limited alcohol intake, and a healthy diet have been identified as blood pressure reducing measures [45-47].

Strengths and limitations – The biggest strength of this study is the BHIS's large, nationally representative sample size. Additionally, the BHIS uses standardised questions, which are easily repeated and compared in other studies. However, a limitation of this survey is that most measures rely on self-reporting. Measures such as BMI tend to be underestimated due to height overestimation and weight underestimation [48]. Similarly, other health behaviours and having hypertension can be wrongly estimated when relying on self-reporting [49, 50]. To avoid this effect on BP outcomes, we also investigated objective BP measurements of the BELHES.

Furthermore, to determine the diet score, the frequencies of eating fruits, vegetables, sodas and sweet or salty snacks were taken into account. More complex diet questionnaires exist that are better at estimating diet quality. Similarly, only leisure activities were used as a measure for exercise. Adding the number of hours per day spent sitting or standing, or the activities performed at work would give a better overview of overall physical activity levels. However, these measures were not taken into account to avoid

complexity of the healthy lifestyle score. The simplicity of this score is a great strength. This score can easily be repeated and used in other studies to score lifestyle, enabling easier comparison with other studies.

An additional limitation of this study is that attributing equal weight to health behaviours simplifies their individual impact on mental and cardiovascular health. However, this broad and straightforward approach is more feasible than more complex algorithms [51]. Moreover, weighting individual health behaviours depends on their association with mental or cardiovascular health outcomes. An unweighted score allows for lifestyle to be associated with a wide range of outcomes.

Finally, possibly the biggest limitation of this study is that due to the cross-sectional nature of this study, we were unable to determine the direction of the associations between lifestyle and mental and cardiovascular health. Therefore, an exaggerated association due to reverse causality cannot be refuted [52]. Further longitudinal research is warranted to determine causality.

CONCLUSION

In the current study, we showed that a healthy lifestyle, consisting of the combined healthy behaviours of a healthy BMI, regular recreational sport, non-smoking, low alcohol consumption, and consuming a diet with sufficient fruit and vegetables, low in sweet and salty snacks is associated with lower odds of impaired mental and cardiovascular health in the Belgian population. In accordance with other studies, these findings suggest that stronger adherence to lifestyle guidelines should be promoted and implemented in Belgians' lifestyle. As a result, mental and cardiovascular health disorders can be prevented and improved, leading to decreased disease prevalence, hospitalisation, and healthcare costs.

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Author contributions – Prof. Dr. TSN, Dr. NDS, and PH designed the research. MD created the lifestyle score, performed data analyses and wrote the manuscript. PH carefully edited the manuscript. Dr. NDS and PH supervised the study. Dr. NDS, Dr. EMDC, and PH advised on creating the lifestyle score, research approach, statistical analysis, and manuscript.

SUPPLEMENTARY MATERIALS

Supplementary Table 1 – Weighted general characteristics and health behaviour characteristics of the study population (n=5997).		
Variable		**N (%) or Mean ± SD**
General characteristics		
Age, years		48.4 ± 27.2
Gender	Male	2924 (49.5)
Highest educational level of household	Up to lower secondary education	1004 (15.8)
	Higher secondary education	1795 (32.1)
	Higher education	3193 (52.1)
Region	Flanders	2467 (59.0)
	Brussels	1387 (9.0)
	Wallonia	2143 (32.0)
Nationality	Belgian	5196 (90.5)
	Non-Belgian (EU)	561 (6.0)
	Non-EU	240 (3.6)
Perceived social support	Poor	944 (15.3)
	Intermediate	2964 (49.5)
	Strong	2089 (35.2)
Health behaviours		
BMI	Underweight	164 (2.6)
	Normal weight	2828 (48.1)
	Overweight	2054 (33.1)
	Obese	951 (16.2)
Physical activity	Sedentary activities	1778 (28.5)
	Light act. <4 h/w	1377 (22.4)
	Light act. ≥4 h/w or recreational sport <4 h/w	1800 (30.2)
	Recreational sport ≥4 h/w or intense training	1042 (18.9)
Smoking status	Regular smokers	995 (17.3)
	Occasional smokers	158 (2.7)
	Former smokers	1454 (23.0)
	Non-smokers	3390 (57.0)
Alcohol consumption	<1 drink/week or abstainers	2898 (48.9)
	1–7 drinks/week	1761 (29.2)
	8–14 drinks/week	726 (11.6)
	15–21 drinks/week	320 (5.7)
	≥22 drinks/week	292 (4.6)
Diet	Diet score 0–9	1749 (31.6)
	Diet score 10–12	2599 (42.8)
	Diet score 13–16	1649 (25.5)
Healthy lifestyle score	1	847 (14.6)
	2	1921 (31.7)
	3	2358 (39.2)
	4	871 (14.5)
h/w: hours per week		

Supplementary Table 2 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and psychological distress (with 95% confidence interval [CI] and *p*-values).

Variable	Psychological distress		
	OR	**95% CI**	***p*-value**
Age (years)	0.99	0.98 – 0.99	< 0.001
Gender (female)	1.96	1.67 – 2.29	< 0.001
Highest educational level of household			0.104
Up to lower secondary education	Ref		
Higher secondary education	0.85	0.67 – 1.09	0.204
Higher education	1.05	0.83 – 1.32	0.686
Region			0.014
Flanders	Ref		
Brussels	1.29	1.06 – 1.57	0.011
Wallonia	1.24	1.04 – 1.49	0.020
Nationality			0.851
Belgian	Ref		
Non-Belgian (EU)	0.92	0.67 – 1.26	0.585
Non-EU	0.95	0.60 – 1.51	0.825
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.38	0.31 – 0.46	< 0.001
Strong	0.28	0.22 – 0.35	< 0.001

Supplementary Table 3 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and low life satisfaction (with 95% confidence interval [CI] and *p*-values).

Variable	Low life satisfaction		
	OR	**95% CI**	***p*-value**
Age (years)	1.00	0.99 – 1.00	0.303
Gender (female)	1.60	1.25 – 2.05	< 0.001
Highest educational level of household			< 0.001
Up to lower secondary education	Ref		
Higher secondary education	0.61	0.44 – 0.84	0.003
Higher education	0.51	0.38 – 0.68	< 0.001
Region			< 0.001
Flanders	Ref		
Brussels	1.95	1.48 – 2.58	< 0.001
Wallonia	1.77	1.36 – 2.30	< 0.001
Nationality			0.032
Belgian	Ref		
Non-Belgian (EU)	0.99	0.67 – 1.47	0.971
Non-EU	2.17	1.20 – 3.89	0.010
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.30	0.23 – 0.39	< 0.001
Strong	0.14	0.10 – 0.20	< 0.001

Supplementary Table 4 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and suboptimal vital energy (with 95% confidence interval [CI] and *p*-values).

Variable	Suboptimal vital energy		
	OR	95% CI	*p*-value
Age (years)	0.98	0.97 – 0.99	< 0.001
Gender (female)	1.95	1.58 – 2.36	< 0.001
Highest educational level of household			0.566
Up to lower secondary education	Ref		
Higher secondary education	1.01	0.73 – 1.39	0.969
Higher education	1.14	0.83 – 1.55	0.424
Region			< 0.001
Flanders	Ref		
Brussels	1.57	1.21 – 2.05	< 0.001
Wallonia	1.65	1.28 – 2.12	< 0.001
Nationality			0.945
Belgian	Ref		
Non-Belgian (EU)	1.05	0.73 – 1.52	0.788
Non-EU	1.07	0.60 – 1.93	0.820
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.63	0.43 – 0.93	0.018
Strong	0.32	0.22 – 0.47	< 0.001

Supplementary Table 5 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and generalised anxiety disorder (with 95% confidence interval [CI] and *p*-values).

Variable	Generalised anxiety disorder		
	OR	95% CI	*p*-value
Age (years)	0.99	0.98 – 1.00	0.003
Gender (female)	2.54	2.01 – 3.21	< 0.001
Highest educational level of household			0.490
Up to lower secondary education	Ref		
Higher secondary education	1.16	0.83 – 1.63	0.393
Higher education	0.99	0.72 – 1.38	0.966
Region			< 0.001
Flanders	Ref		
Brussels	1.17	0.88 – 1.55	0.286
Wallonia	1.61	1.25 – 2.07	< 0.001
Nationality			0.919
Belgian	Ref		
Non-Belgian (EU)	1.04	0.70 – 1.55	0.848
Non-EU	1.15	0.56 – 2.38	0.697
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.30	0.23 – 0.39	< 0.001
Strong	0.21	0.15 – 0.29	< 0.001

Supplementary Table 6 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and major depressive disorder (with 95% confidence interval [CI] and *p*-values).

Variable	Major depressive syndrome		
	OR	95% CI	*p*-value
Age (years)	1.00	0.99 – 1.01	0.623
Gender (female)	1.85	1.25 – 2.73	0.002
Highest educational level of household			0.988
Up to lower secondary education	Ref		
Higher secondary education	0.99	0.60 – 1.62	0.952
Higher education	0.96	0.60 – 1.55	0.880
Region			0.007
Flanders	Ref		
Brussels	1.42	0.88 – 2.30	0.156
Wallonia	1.88	1.27 – 2.78	0.002
Nationality			0.509
Belgian	Ref		
Non-Belgian (EU)	1.39	0.72 – 2.66	0.327
Non-EU	1.63	0.48 – 5.52	0.434
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.24	0.16 – 0.35	< 0.001
Strong	0.14	0.08 – 0.24	< 0.001

Supplementary Table 7 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and suicidal ideation (with 95% confidence interval [CI] and *p*-values).

Variable	Suicidal ideation		
	OR	95% CI	*p*-value
Age (years)	0.99	0.98 – 1.00	0.010
Gender (female)	1.29	0.87 – 1.91	0.203
Highest educational level of household			0.222
Up to lower secondary education	Ref		
Higher secondary education	1.04	0.64 – 1.68	0.888
Higher education	0.73	0.45 – 1.16	0.182
Region			0.185
Flanders	Ref		
Brussels	1.38	0.93 – 2.03	0.109
Wallonia	1.37	0.90 – 2.08	0.147
Nationality			0.135
Belgian	Ref		
Non-Belgian (EU)	0.62	0.29 – 1.31	0.209
Non-EU	0.49	0.21 – 1.14	0.098
Perceived social support			< 0.001
Poor	Ref		
Intermediate	0.30	0.20 – 0.45	< 0.001
Strong	0.14	0.08 – 0.22	< 0.001

Supplementary Table 8 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and cardiovascular disease (with 95% confidence interval [CI] and *p*-values).

Variable	Cardiovascular disease		
	OR	**95% CI**	***p*-value**
Age (years)	1.07	1.06 – 1.08	< 0.001
Gender (female)	0.78	0.56 – 1.10	0.159
Highest educational level of household			0.073
Up to lower secondary education	Ref		
Higher secondary education	0.63	0.41 – 0.97	0.036
Higher education	0.91	0.58 – 1.43	0.695
Region			0.074
Flanders	Ref		
Brussels	0.60	0.39 – 0.93	0.023
Wallonia	0.83	0.58 – 1.19	0.314
Nationality			0.331
Belgian	Ref		
Non-Belgian (EU)	0.90	0.43 – 1.90	0.782
Non-EU	0.30	0.06 – 1.48	0.141

Supplementary Table 9 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and self-reported high BP (with 95% confidence interval [CI] and *p*-values).

Variable	Self-reported high BP		
	OR	**95% CI**	***p*-value**
Age (years)	1.06	1.06 – 1.07	< 0.001
Gender (female)	0.95	0.79 – 1.15	0.608
Highest educational level of household			0.515
Up to lower secondary education	Ref		
Higher secondary education	0.99	0.75 – 1.30	0.939
Higher education	1.12	0.86 – 1.46	0.402
Region			0.032
Flanders	Ref		
Brussels	0.81	0.64 – 1.03	0.084
Wallonia	1.14	0.92 – 1.40	0.238
Nationality			0.288
Belgian	Ref		
Non-Belgian (EU)	1.13	0.80 – 1.62	0.489
Non-EU	1.52	0.87 – 2.64	0.142

Supplementary Table 10 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and high blood cholesterol (with 95% confidence interval [CI] and *p*-values).

Variable	High blood cholesterol		
	OR	95% CI	*p*-value
Age (years)	1.05	1.04 – 1.06	< 0.001
Gender (female)	0.88	0.73 – 1.06	0.171
Highest educational level of household			0.556
Up to lower secondary education	Ref		
Higher secondary education	1.01	0.78 – 1.31	0.938
Higher education	1.21	0.87 – 1.45	0.379
Region			0.038
Flanders	Ref		
Brussels	0.74	0.58 – 0.93	0.012
Wallonia	0.94	0.76 – 1.16	0.550
Nationality			0.570
Belgian	Ref		
Non-Belgian (EU)	1.00	0.65 – 1.53	0.994
Non-EU	1.36	0.77 – 2.42	0.290

Supplementary Table 11 – Adjusted odds ratios (OR) of the covariates in the association between the healthy lifestyle score and high or potentially high BP (with 95% confidence interval [CI] and *p*-values).

Variable	High or potentially high BP[a]		
	OR	95% CI	*p*-value
Age (years)	1.09	1.07 – 1.11	< 0.001
Gender (female)	0.81	0.54 – 1.20	0.291
Highest educational level of household			0.954
Up to lower secondary education	Ref		
Higher secondary education	1.10	0.61 – 1.99	0.761
Higher education	1.06	0.59 – 1.91	0.838
Region			0.178
Flanders	Ref		
Brussels	0.71	0.41 – 1.24	0.226
Wallonia	1.24	0.81 – 1.91	0.318
Nationality			0.020
Belgian	Ref		
Non-Belgian (EU)	1.17	0.55 – 2.50	0.686
Non-EU	3.95	1.51 – 10.34	0.005

[a]BELHES subset (n=888)

Supplementary Table 12 – Adjusted differences (%) of the covariates in average systolic blood pressure in the association with the healthy lifestyle score (with 95% confidence interval [CI] and *p*-values).

Variable	Systolic BP[a]		
	% difference	95% CI	*p*-value
Age (years)	0.41	0.36 – 0.47	< 0.001
Gender (female)	-7.09	-8.57 – -5.59	< 0.001
Highest educational level of household			0.295
Up to lower secondary education	Ref		
Higher secondary education	0.76	-2.14 – 3.74	0.610
Higher education	-0.85	-3.54 – 1.91	0.539
Region			0.300
Flanders	Ref		
Brussels	1.79	-0.59 – 4.23	0.141
Wallonia	0.10	-1.91 – 2.15	0.923
Nationality			0.635
Belgian	Ref		
Non-Belgian (EU)	0.90	-2.09 – 3.98	0.559
Non-EU	1.82	-2.42 – 6.25	0.405

[a]BELHES subset (n=888)

Supplementary Table 13 – Adjusted differences (%) of the covariates in average diastolic blood pressure in the association with the healthy lifestyle score (with 95% confidence interval [CI] and *p*-values).

Variable	Diastolic BP[a]		
	% difference	95% CI	*p*-value
Age (years)	0.21	0.15 – 0.27	< 0.001
Gender (female)	-2.11	-3.75 – -0.44	0.014
Highest educational level of household			0.613
Up to lower secondary education	Ref		
Higher secondary education	1.26	-1.73 – 4.34	0.412
Higher education	1.41	-1.41 – 4.32	0.328
Region			0.284
Flanders	Ref		
Brussels	0.30	-2.11 – 2.77	0.809
Wallonia	1.66	-0.44 – 3.80	0.122
Nationality			0.144
Belgian	Ref		
Non-Belgian (EU)	2.75	-0.40 – 5.99	0.087
Non-EU	2.78	-1.66 – 7.42	0.222

[a]BELHES subset (n=888)