Original Research Article

Development of a point-based model for poor academic performance in Japanese university students based on lifestyle risk factors: a prospective cohort study

Abstract

Aims: Multiple lifestyle behaviors have been linked with poor academic performance (AP) in undergraduate students. It is unknown whether a risk prediction model that incorporates a combination of different lifestyle behaviors would predict the risk of poor AP.

Study design: a population-based prospective study

Methods: A total of 2,282 eligible participants (men: 66%) aged 18 to 22 years were followed up for four years. Poor AP was defined as a grade point average (GPA) of less than 2.0. Cox proportional hazards models were used to identify lifestyle behaviors associated with the development of poor AP, and a score was created from predictors in the final model.

Results: During a median follow-up period of four years, 440 (29.2%) men and 111 (14.3%) women developed poor AP. The final model for poor AP in men included low frequency of breakfast intake, dietary intake ups and downs, shorter weekday study time,

longer weekday video game time, doing exercise almost every day, self-rated irregular lifestyle. In women, alcohol intake once or more per week, low frequency of breakfast intake, dietary intake ups and downs were included in the final model for poor AP. The risk prediction models showed good discriminatory abilities (C statistics: 0.73, 95% confidence interval [CI]: 0.67, 0·78 for women; and 0·70, 95% CI: 0·66, 0·74 for men). Conclusions: This risk prediction model incorporating multiple unhealthy lifestyle behaviors predicts poor AP with good discrimination ability.

Keywords: Multiple health behaviors, Lifestyles, Health promotion, Risk prediction model, University students, Academic performance.

Introduction

It is generally accepted that successful academic performance (AP) plays an important role during the undergraduate period and in predicting future social and occupational success,[1] highlighting the need for the prevention of poor AP in undergraduate students. The identification of individuals who are at high risk of poor AP is an important step toward prevention.

Previous cross-sectional studies have demonstrated strong relationships between

several lifestyle behaviors (such as drinking habits, breakfast intake) and AP.[2-4] However, it remains unclear whether such lifestyle behaviors would predict poor AP in a prospective cohort study. More importantly, to the authors' best knowledge, it is unknown whether a combination of multiple lifestyle behaviors could better explain the variation in the risk of developing poor AP in undergraduate students. Findings from a recent study showed that multiple lifestyle behaviors (diet, physical activity, sleep, and screen time) have a cumulative effect on academic outcomes in youth.[5] Thus, it could be expected that a multi-domain model that incorporates a combination of different lifestyle behaviors would more accurately predict the risk of poor AP.

Therefore, the purpose of this four-year follow-up study was to develop a risk prediction model incorporating multiple lifestyle behaviors to predict poor AP in undergraduate students.

Methods

Study design

This study conducted a four-year population-based prospective study, which aimed at improving students' physical and mental health at K. University which is a national university in Japan. Baseline surveys were performed in May and June in 2010 and

during the same period in 2011. AP data were provided by the administration every semester until the last academic year.

Participants and procedures

The participants in the present study were 5,359 undergraduate students, aged from 18 to 22 years, who were newly enrolled at K. university in 2010 and 2011. The baseline survey was administered in Physical Education class in May and June within the first semester. The objective of the survey was explained on the first page of the questionnaire, and informed consent for participation was requested. After excluding 618 participants who refused informed consent for the questionnaire, 2,447 participants who refused informed consent for their AP data, and 12 participants whose data on key variables were missing, we had a final sample size of 2,282 eligible participants (1,506 men and 776 women) for the present analysis (Appendix Figure 1.in the supplemental material).

Academic performance

Academic performance during the four-year follow-up period was assessed by grade point average (GPA). GPA was calculated using the credit-weighted sum of the grades for all courses divided by total credits. In this study, GPA was assigned on a scale from 0.0 to

4.0. Any student's GPA point newly identified as less than 2.0 during the four-year follow-up period was deemed to be the outcome in this study, that is, the student was then assigned to the lower GPA group (GPA from 0.0 to 1.9) rather than the higher GPA group (2.0 to 4.0). This cut-off value was selected based on a university regulation that if a student's GPA score is less than 2.0 at the end of his or her second academic year, that student is not eligible to enter the third academic year. Therefore, this cut-off value is considered appropriate for the purposes of this study.

Sociodemographic characteristics and lifestyle behaviors

Sociodemographic characteristics and lifestyle behavior data were part of the database of this study, in which the reliability and validity of the survey were tested and the details of the survey have been published elsewhere.[6] The sociodemographic characteristics comprised age, sex, residence status (living alone in an apartment/living in the dormitory/living with parents), and yes or no responses to items regarding part-time jobs and financial difficulties.

The lifestyle behavior variables consisted of four sections: dietary habits, sleeping habits, exercise habits, and other lifestyle behaviors. Dietary habits were assessed on regular breakfast consumption (eating breakfast almost every day/sometimes/rarely or

never), and snacking habits (never/sometimes), with snacks defined as any food outside main meals. In addition, we included a variable for dietary intake ups and downs using a binominal scale for responses to the question “Do you sometimes eat too much or less than normal?” Regarding impaired diet habits, we used variables about paying attention to salt intake (yes/no). Sleeping habits included bedtime (24:00 or earlier/later than 24:00), waking time (07:00 or earlier/later than 07:00), inadequate sleep (yes/no), and always napping during the day (yes/no). Exercise habits were assessed on the frequency of physical activity (almost every day/sometimes or never). Other lifestyle behavior variables included drinking habits (never/once or more per week), weekday study time (more than one hour/less than one hour), weekday video games (more than one hour/less than one hour), and a self-rated lifestyle variable using a binominal scale for responses to the question “Do you think you have a regular lifestyle?”

Statistical analysis

Multiple Cox proportional hazard models stratified by sex were derived to assess the risk of poor AP. Hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated for the incident risk of poor AP according to lifestyle behaviors at baseline. To develop the final predictive model, backward selection was used to select the variables ($p<0.05$). This

study developed the risk score using the β regression coefficient values of the lifestyle behavior variables that were statistically significant (p-value less than 0.05) in a Cox proportional hazard model using an easily calculable value.[7] The risk score for each variable was an integer score multiplied by 10 and a β regression coefficient value. The discriminatory abilities of the final risk prediction models were evaluated by overall concordance statistics (C statistics) using 200 bootstrapping samples.[8] We divided the subjects into four groups (Q1 to Q4) based on the quartile of total lifestyle risk score. In addition, this study calculated the cumulative incidence rate of poor AP (GPA<2.0) during the four years by sex. A two-sided p-value of less than 0.05 was considered to be statistically significant. All analyses were completed using SAS (Version 9.4, SAS Institute, Cary, NC, USA). The computation was carried out using the computer resource offered under the category of General Projects by the Research Institute for Information Technology, K. University.

Results

A total of 2,282 participants were enrolled in the present study. No participant dropped out during the four-year follow-up period. Table 1 shows the baseline characteristics of the participants by sex. The 2010 cohort included 456 participants, and the 2011 cohort

included 1,826 participants. The participants' ages ranged from 18 years to 22 years with a mean age of 18.3 years (SD 0.9) and 18.3 years (SD 0.6) in men and women, respectively. Almost all variables showed statistically significant differences by sex.

The lifestyle behavior factors associated with the risk of poor AP during the four years are shown in Tables 2. In both men and women, sometimes or never eat breakfast and dietary intake ups and downs were positively associated with poor AP. In men, self-rated irregular lifestyle, shorter weekday study time, longer weekday video game time, and doing exercise almost every day were significantly associated with a higher incident risk of poor AP. As for women, alcohol intake once or more per week was significantly associated with a higher incident risk of poor AP. The risk prediction models showed good discriminatory abilities with C statistics of 0.73 (95% CI: 0.67, 0.78) for women and 0.70 (95% CI: 0.66, 0.74) for men.

The crude cumulative incidences of poor AP during the four follow-up periods classified according to the quartile of the total score of lifestyle behaviors are shown in Figure 1 for men and Figure 2 for women. For men, according to the levels of lifestyle behavior risk score arranged from low to high, a trend of continuous increase is demonstrated in the crude cumulative incidences of poor AP starting at 13.9% in Q1, and increasing to 21.5% in Q2, 35.2% in Q3, and ultimately 48.3% in Q4 (p-value of less than

0.05 for Q2-Q4 compared with Q1). The cumulative incidence of poor AP in women was consistently lower than that in men (7.6% in Q1, 11.9% in Q2, 15.6% in Q3, and 25.8% in Q4; p-value of less than 0.05 for Q3 and Q4 compared with Q1).

Table 3 shows the association between levels of lifestyle behaviors and risk of poor AP after adjusting the cohort. In both sexes, the incident risks of poor AP in Q2, Q3 and Q4 are significantly higher than in Q1 (all p-values of less than 0.05). Moreover, with one-point increments of the total scores of lifestyle behaviors, the HR (95% CI) for poor AP was 1.10 (1.09 to 1.12) in men and 1.11 (1.07 to 1.14) in women.

The characteristics of lifestyle behavior statistically associated with poor AP are shown in Appendix Table 1(supplemental material) according to total score levels. For men, the percentage of participants without a regular lifestyle, and with a low frequency of breakfast intake, and a later wake time on weekdays increased substantially from the lowest group, Q1, to Q4. Similar results were found in women, in whom the percentage of participants with a low frequency of breakfast intake also shows a substantial increase from Q1 to Q4.

Discussion

The present prospective study using four-year follow-up data developed a risk prediction

model that investigated the positive associations between more unhealthy lifestyle behaviors and a higher incident risk of poor AP among Japanese undergraduate students. Moreover, the total score of unhealthy lifestyle behaviors was significantly associated with an increased risk of poor AP in a linear dose-response manner in both men and women. This risk prediction model foresees a significant protective effect of healthy lifestyle behaviors against the risk of poor AP that continues throughout the entire undergraduate period.

In the present study, an irregular lifestyle, shorter study time on weekdays, and low frequency of breakfast intake were positively associated with an increased risk of poor AP among men; this is consistent with previous studies.[9,10] However, in contrast to other studies, we found that men with a high frequency of exercise activity tended to have a high risk of poor AP.[11,12] Undergraduate students are likely to experience changes in lifestyle behaviors at the beginning of their new university life and might to tend to spend too much time on physical activity to the detriment of their AP. In addition, other studies also suggest that high-frequency exercise activities may be associated with low concentration during school time due to fatigue.[13] Our findings draw attention to the importance of an appropriate frequency of exercise, while also highlighting the need to maintain a balanced schedule to promote health and manage AP.

For women, this study showed that drinking habits, low frequency of breakfast intake, and dietary intake ups and downs were significantly associated with an increased risk of poor AP. The women's risk prediction model showed several differences compared with that of men. First, regarding the association between lifestyle behaviors and poor AP, fewer variables were observed in women, which could be associated with the fact that the cumulative incidence rate of poor AP (GPA <2.0) during the 4 years for women was lower than that for men. Furthermore, some variables that we did not measure, such as psychological factors and interpersonal relationships, may have influenced women's AP status.[14] Second, compared with men, women who have drinking habits showed an increased risk of poor AP, which is consistent with a previous study that found a similar negative association between alcohol intake and poor AP among American undergraduate students.[15] Regarding the reasons for the association between alcohol intake and poor AP, recent evidence from research on undergraduates suggests that alcohol intake is negatively associated with stress level.[16] In the present study, the association between alcohol intake once or more per week and increased risk of poor AP in women may have been confounded by some type of psychological distress that occurred more often in women.

In this prospective study, both men and women with a low frequency of breakfast

intake tended to have an increased risk of poor AP, which is consistent with previous findings regarding elementary and high school students.[17,18] However, the findings regarding elementary and high school students may not be applicable to undergraduate students since the pre-university-level curriculum consists primarily of foundational and immovable courses, with the result that all students' waking times tend to be similar and students rarely wake up late enough to have to skip breakfast in the morning. In contrast, undergraduate students' daily schedules are more flexible. Thus, the fact that an undergraduate student eats breakfast almost every day may reflect an organized and regular rhythm of waking time and other lifestyle behaviors that influence AP potentiality. Daily breakfast intake is known to positively affect the overall daily nutrient intake, which is linked with improved cognition processes, and better school performance and attendance rates.[19] Although the protective association between regular breakfast consumption and AP has been clarified based on evidence from numerous cross-sectional data, little is known about any longitudinal protective effect of daily breakfast consumption on AP, [20] though the results of the present study support this prospective protective effect.

To the best of our knowledge, this is the first study that used a risk prediction model to explore the associations between multiple lifestyle behaviors and AP. Compared with

other studies that measured a single lifestyle behavior or adjusted for related lifestyle behaviors, the present study suggests that the combined effects of various unhealthy lifestyle behaviors, reflected in the increasing total scores of lifestyle behaviors, are associated with a higher incident risk of poor AP. Several possible reasons may underlie the additive prediction of various unhealthy lifestyle behaviors on poor AP. First, there is a strong correlation between certain lifestyle behaviors; for example, late waking time may be associated with skipping breakfast. In addition, according to the Center for Disease Control, unhealthy lifestyle behaviors are responsible for the development of chronic diseases.[21] Eventually, the potential influence of impaired physical or mental status seems to strengthen the increasing risk of poor AP through various unhealthy lifestyle behaviors. [22]

Thus, based on this prospective study, using a risk score to predict and weigh poor academic performance-related factors to apply primary prevention in cases of intense levels of unhealthy lifestyle behaviors is practical and convenient for universities and undergraduates. Using our proposed risk prediction model will help undergraduate students to easily determine their potential risk of poor AP and to improve the most urgent lifestyle behaviors to prevent the incident risk of poor AP in the future. The result of this study draws attention to the health promotion policy for undergraduate university

students, this is, it might be useful to prevent students' poor academic AP according to improving unhealthy lifestyle behaviors in the early stage.

This four-year population-based prospective study has several strengths. First, the risk prediction model created from lifestyle behaviors is accurate in predicting the risk of poor AP. Therefore, based on this prospective study, using a risk score to predict and weigh poor AP-related factors in order to apply primary prevention in cases of intense levels of unhealthy lifestyle behaviors is both practical and convenient for universities and their undergraduates. Second, this study used a population-based prospective design, thus providing overall insight into the longitudinal effect of lifestyle behaviors on AP during the four-year period of undergraduate study. Finally, we used data from a large sample of Japanese undergraduate students, providing basic evidence supporting the relationship between healthy lifestyle behaviors and AP during the undergraduate period.

The present study had certain limitations. First, the risk prediction model should be validated in other undergraduate students in the future. Second, our study was limited to AP data before the subjects enrolled in the university. Although baseline AP data might account for some AP findings during the undergraduate period, all the participants enrolled at this university according to its admission criteria, which are based on the students' results on the National Center for University Entrance Examinations; that is,

almost all the participants had a similar crude AP at baseline, with little significant difference. Third, the definition of poor AP in this study might not be applicable in different faculties or at other universities. Finally, it should be noted that mental health factors that this study did not include, but we already confirmed the association between mental health and academic performance in the other study.[23]

This study used multiple unhealthy lifestyle behaviors to create a risk prediction model that showed a good discriminatory ability to predict an increased risk of poor academic performance during four academic years among undergraduate students. This study draws attention to the role of healthy lifestyle behaviors in the development of academic performance and could help to identify undergraduate students who might benefit from intensive lifestyle improvement.

Data Availability

The data used in this study is not publicly available due to privacy considerations.

Ethical considerations

Permission to conduct the study was obtained from the Ethics Committee of the Institutional Review Board of Health Science, K. University, and written informed

consent was obtained from all subjects before administering the questionnaire.

Contributors

TSC contributed to the study conception, design, formal statistical analyses, interpretation, and drafting of the manuscript. TC contributed to data curation and interpretation, and reviewed the analysis and the manuscript. TS contributed to interpretation, and reviewed the analysis and the manuscript. ST, HF, and YM contributed to data preparation and interpretation. SK contributed to the study conception and interpretation. HK as the corresponding author conceptualized and supervised the whole study, was responsible for obtaining funding, provided guidance on methodology, performed statistical analyses, interpreted results, and critically reviewed the manuscript. HK, TC and TSC accessed and verified all data. All authors had final responsibility for the decision to submit the manuscript for publication.

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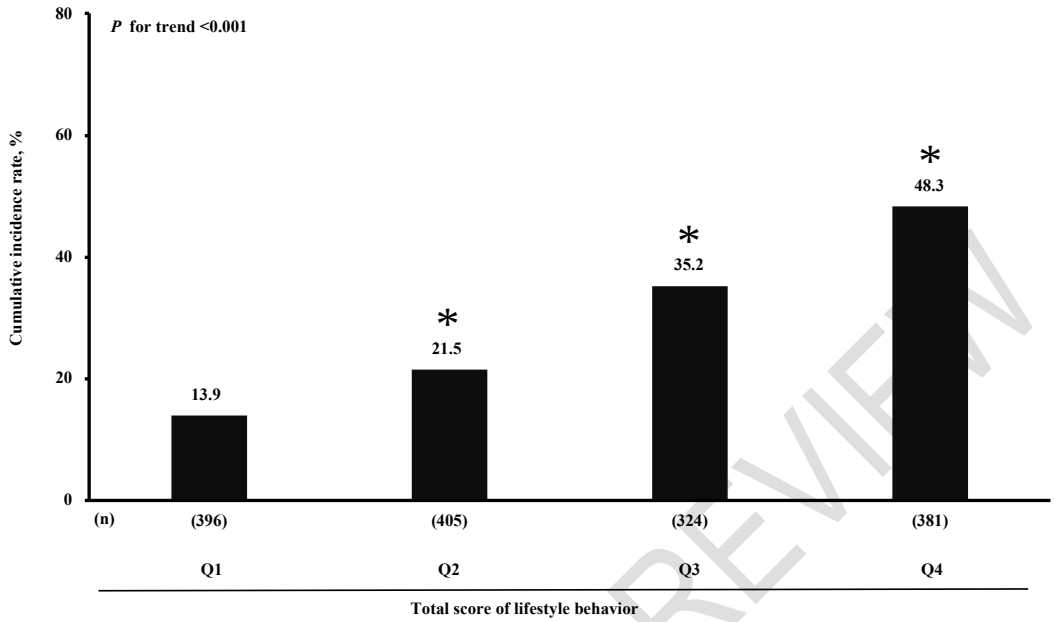
Figure 1.

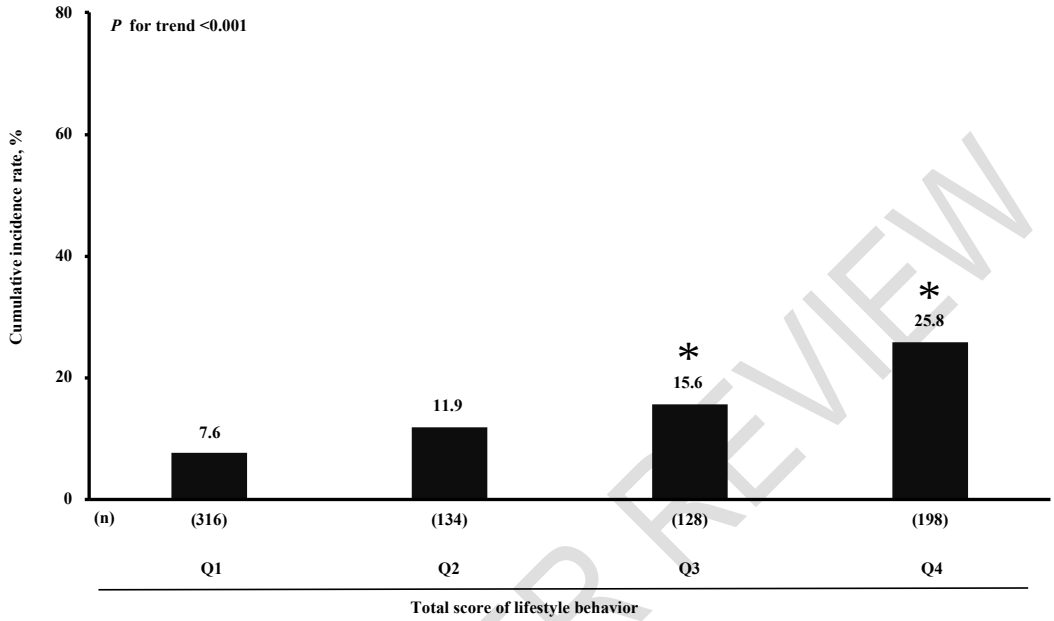
Cumulative incidence rate of poor academic performance (GPA <2.0) during four years among men



The quartile cutoff points were the following total scores of lifestyle behaviors: -3, 2, 7.
*p <0.05 vs. Q1 group

Figure 2.

Cumulative incidence rate of poor academic performance (GPA <2.0) during four years among women



The quartile cutoff points were the following total scores of lifestyle behaviors: 0, 5, 11.
*p <0.05 vs. Q1 group

Table 1. Characteristics of study participants

	Men n = 1506	**Women** n = 776	***P* value**
Age, years	18.3 ± 0.9	18.3 ± 0.6	0.01
Living in the dormitory, No %	1403 (93.2)	722 (93.0)	0.91
Part-time job, Yes %	248 (16.5)	196 (25.3)	<0.001
Financial difficulty, Yes %	169 (11.2)	68 (8.8)	0.07
Self-rated lifestyle, Irregular %	671 (44.6)	322 (41.5)	0.16
Weekday study time, <1 h %	973 (64.6)	450 (58.0)	<0.001
Weekday video game time, ≥1 h %	287 (19.1)	32 (4.1)	<0.001
Drinking habits, Once or more per week %	585 (38.8)	255 (32.9)	0.01
Exercise frequency, Sometimes or never %	1282 (85.1)	729 (93.9)	<0.001
Breakfast habits, %			<0.001
Sometimes	217 (14.4)	77 (9.9)	
Never	159 (10.6)	41 (5.3)	

Snacking habits, Sometimes %	1088 (72.2)	650 (83.8)	<0.001
Paying attention to salt intake, No %	1245 (82.7)	626 (80.7)	0.24
Dietary intake ups and downs, Yes %	412 (27.4)	311 (40.1)	<0.001
Always napping during the day, Yes %	869 (57.7)	532 (68.6)	<0.001
Bedtime, later than 24:00 %	1311 (87.0)	647 (83.4)	0.02
Waking time, later than 07:00 %	544 (36.1)	134 (17.3)	<0.001
Inadequate sleep, Yes %	724 (48.1)	417 (53.7)	0.01

Data are represented as mean (standard deviation) or n (%).

Statistical significance was based on chi-square tests or t-tests, as appropriate.

Table 2. Association between lifestyle behaviors and risk of poor academic performance during four years

		Multi-variable adjusted HR	95% CI	*P* value	β coefficient	Score
MEN						
Self-rated lifestyle	Regular	Ref.				0
	Irregular	1.64	1.33, 2.01	<0.001	0.49	5
Weekday study time	≥1 h	Ref.				0
	<1 h	1.44	1.16, 1.79	<0.01	0.37	4
Weekday video game time	<1 h	Ref.				0
	≥1 h	1.53	1.22, 1.91	<0.01	0.43	4
Exercise frequency	Almost every day	Ref.				0
	Sometimes or never	0.52	0.41, 0.67	<0.001	-0.65	-7
Breakfast habits	Almost every day	Ref.				0
	Sometimes	1.49	1.16, 1.91	<0.01	0.40	4
	Never	1.70	1.29, 2.24	<0.001	0.53	5
Dietary intake ups and downs	No	Ref.				0
	Yes	1.24	1.01, 1.53	0.04	0.21	2
Wake time	07:00 or earlier	Ref.				0
	Later than 07:00	1.43	1.17, 1.74	<0.001	0.36	4
WOMEN						
Drinking habits	Never	Ref.				0
	Once or more per week	1.78	1.22, 2.60	<0.01	0.58	6
Breakfast habits	Almost every day	Ref.				0
	Sometimes	2.02	1.22, 3.37	0.01	0.70	7

	Never	2.93	1.64, 5.25	<0.001	1.07	11
Dietary intake ups and downs	No	Ref.				0
	Yes	1.70	1.15, 2.52	0.01	0.53	5

HR: Hazard ratio; CI: Confidence interval.

Adjusted for the cohort, sociodemographic variables, and other lifestyle behavior variables.

Table 3. Association between lifestyle behavior scores and the risk of poor academic performance (GPA <2.0)

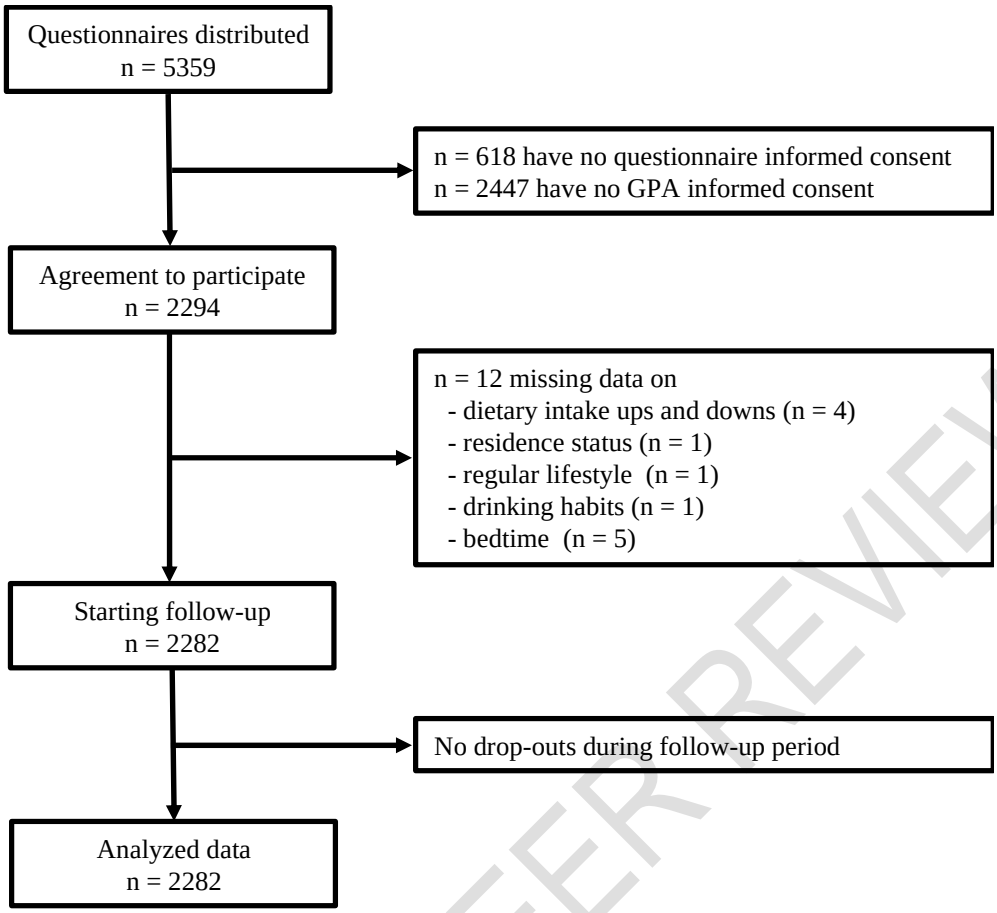
	Number of events/participants	**Multi-variable adjusted HR (95%CI)**	***P* value**
Men			
Q1 (low score)	55/396	1.00 (Ref.)	Ref.
Q2	87/405	1.58 (1.13, 2.22)	0.01
Q3	114/324	2.88 (2.09, 3.97)	<0.001
Q4 (high score)	184/381	4.36 (3.22, 5.89)	<0.001
Per one-point increment	440/1506	1.10 (1.09, 1.12)	<0.001
Women			
Q1 (low score)	24/316	1.00 (Ref.)	Ref.
Q2	16/134	1.61 (0.85, 3.02)	0.14
Q3	20/128	2.18 (1.21, 3.95)	0.01
Q4 (high score)	51/198	3.87 (2.38, 6.29)	<0.001
Per one-point increment	111/776	1.11 (1.07, 1.14)	<0.001

HR: Hazard ratio; CI: confidence interval.

The quartile cutoff points were the total scores of lifestyle behaviors: -3, 2, 7 for men, and 0, 5, 11 for women.

Adjusted for the cohort.

Supplementary



Appendix Fig 1. Flowchart of participant selection for this study

Appendix Table 1. Lifestyle behavior characteristics from Q1 to Q4

	Men				Women			
	Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
	(-7 to -3)	**(-2 to 2)**	**(3 to 6)**	**(7 to 22)**	**(0)**	**(1 to 5)**	**(6 to 10)**	**(11 to 22)**
	n=396	**n=405**	**n=324**	**n=381**	**n=316**	**n=134**	**n=128**	**n=198**
Self-rated lifestyle (Irregular)	0 (0)	188 (46.4)	176 (54.3)	307 (80.6)	··	··	··	··
Weekday study time (<1 h)	169 (42.7)	217 (53.6)	251 (77.5)	336 (88.2)	··	··	··	··
Weekday video game time (≥1 h)	22 (5.6)	73 (18.0)	76 (23.5)	116 (30.5)	··	··	··	··
Drinking habits (Yes)	··	··	··	··	0 (0)	0 (0)	116 (90.6)	139 (70.2)
Exercise frequency (Sometimes or never)	396 (100.0)	364 (89.9)	258 (79.6)	264 (69.3)	··	··	··	··
Breakfast habits (Sometimes/Never)	9 (2.3)	39 (9.6)	87 (26.9)	241 (63.3)	0 (0)	0 (0)	12 (9.4)	106 (53.5)
Dietary intake ups and downs (Yes)	18 (4.6)	70 (17.3)	119 (36.7)	205 (53.8)	0 (0)	134 (100.0)	0 (0)	177 (89.4)
Wake time (Later than 07:00)	32 (8.1)	102 (25.2)	131 (40.4)	279 (73.2)	··	··	··	··

Data are represented as n (%).