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Association between lifestyle factors and liver function parameters in the middle-aged and older population

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Abstract

Background Increasing evidence supports a higher risk of abnormal liver function parameters due to unfavorable lifestyles. We therefore explored the synergistic effects of various lifestyle factors on liver function.

Methods 8710 participants from Guangzhou Biobank Cohort Study were included. Five lifestyle factors including non-smoking, non-alcohol use, physically active, non-central and non-general obesity were assessed and a Healthy Lifestyle Index (HLI) (0–5, a higher score indicates healthier lifestyle) was generated. Multivariable linear regression was used to examine the association of HLI with liver function parameters, yielding regression coefficients (βs) and 95% confidence intervals (CIs).

Results A total of 8710 participants with an average age of 64.67 years (standard deviation = 6.07) were included. Of them, 71.65% were women. After adjusting for sex, age, education, family income, and comorbidities, compared with those with HLI of zero, those with HLI scores of 1, 2, 3, 4, and 5 showed a lower ALT level by -5.85 IU/L (95% CI: -10.73, -0.97), -9.97 IU/L (95% CI: -14.53, -5.42), -11.34 IU/L(95% CI: -15.86, -6.82), -12.81 IU/L (95% CI: -17.33, -8.30), and − 14.15 IU/L (95% CI: -18.68, -9.62), respectively (P for trend < 0.001), and a lower AST level by 1.82 IU/L (95% CI: -4.85,1.21), -3.74 IU/L (95% CI: -6.57, -0.91), -4.47 IU/L (95% CI: -7.28, -1.66), -4.69 IU/L (95% CI: -7.49, -1.88), and − 4.75 IU/L (95% CI: -7.57, -1.94), respectively (P for trend < 0.001). Similar trends were observed for a higher ALB level with higher healthy lifestyle scores (P for trend = 0.003).

Conclusions A healthy lifestyle was associated with optimal liver function parameters, highlighting the importance of advocating for health-conscious behaviors to potentially mitigate the incidence of liver dysfunction.

Keywords Lifestyle factors, Liver function parameters, Healthy lifestyle index

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Background

Liver abnormalities are a paramount concern in medical research due to their widespread occurrence and significant health consequences. The liver's pivotal functions in metabolism, detoxification, and protein synthesis highlight its importance. Alterations in hepatic enzyme activity was not only associated with hepatic pathologies but also with extrahepatic conditions, further emphasizing their clinical significance [1, 2]. A cohort study from South Korea showed that serum transaminase values, even within the normal range, could indicate adverse outcomes [3]. Moreover, the increasing prevalence of liver function parameters has also been associated with mortality risk from various causes, indicating their role as prognostic indicators [2, 4].

Previous studies showed a higher risk of liver function abnormalities due to unfavorable lifestyles [5–7]. Environmental factors, such as high body weight [8], inactivity [9], smoking [10], and alcohol consumption [11, 12], play important role in liver impairment. While individual factor analysis provides insights, their combined effect might reveal a more realistic impact on liver health. Healthy Lifestyle Index (HLI), which considers abstinence from alcohol, smoking, obesity, and includes physical activity, was associated with lower risks of chronic diseases such as coronary heart disease [13], type 2 diabetes [14] and metabolic syndrome [15]. However, limited studies have explored its association with liver function parameters.

Lifestyle and quality of life are closely intertwined. Adopting health-promoting lifestyles has shown promise in decreasing the incidence and mortality of liver diseases [2, 16]. Therefore, the current study used data from the Guangzhou Biobank Cohort Study (GBCS) to examine the association of lifestyle-related factors with liver function, aiming to provide evidence-based lifestyle recommendations that improve liver health while reducing disease burdens.

Methods

Study sample

Data of this study were from the GBCS, a collaborative population cohort jointly conducted by the Guangzhou Twelfth People's Hospital, the University of Hong Kong, and the University of Birmingham in the United Kingdom [17]. The study participants were voluntary individuals aged 50 years and above from Guangzhou, who willingly scheduled appointments and attended free health examinations at the Guangzhou Twelfth People's Hospital, along with participating in questionnaire surveys. Details of the GBCS have been reported elsewhere [17].

The GBCS baseline survey was conducted from 2003 to 2008, enrolling a total of 30,430 participants. The GBCS received ethical approval by the Guangzhou Medical Ethics Committee, and all participants provided informed consent on a voluntary basis before participation. The current study specifically used the baseline data collected in 2003–2004, during which serum liver function parameters included alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin (TBil), and albumin (ALB) were measured. Participants with diagnosed liver diseases, including hepatitis B or C virus infections, cirrhosis, and other chronic liver conditions, were excluded from the analysis. Liver function was assessed using serum levels of ALT, AST, albumin, and total bilirubin. After excluding participants who had diagnosed liver disease and with missing data on study variables ($n = 1703$), 8710 participants were included in the current study.

Exposures

Multidimensional exposures were categorized into three domains: demographic and socioeconomic factors, lifestyle factors, and common diseases. Demographic and socioeconomic factors included sex, education, occupation, and household income. Based on previous studies, lifestyle factors including smoking, alcohol consumption, physical activity, sleep duration, central and general obesity were used to construct a composition score [11, 18, 19]. Smoking status was categorized into three groups: never (individuals who have never smoked in their lifetime), former (individuals who previously smoked but currently do not), and current (individuals who answer "yes" to the question "Do you currently smoke?") [18, 20, 21]. Alcohol consumption was assessed using a standardized questionnaire. Participants were categorized into never drinkers (no history of alcohol consumption), former drinkers (ceased alcohol use for at least one year), and current drinkers (alcohol use in the past 12 months) [22, 23]. Physical activity was assessed using the validated Chinese version of the International Physical Activity Questionnaire (IPAQ-C) [24]. The levels of physical activity were categorized into three groups: active (vigorous activity on ≥ 3 days per week, reaching at least 1500 metabolic equivalent task (MET) minutes or moderate activity on ≥ 5 days per week, reaching at least 3000 METs), moderate (vigorous activity on ≥ 3 days per week, reaching 480 METs or any combination of walking, moderate, or vigorous activity on ≥ 5 days per week, reaching 600 METs), and insufficient (participants not meeting criteria for active or moderate-level physical activity), with the insufficient and moderate groups combined due to a small sample size in the insufficient physical activity group [19]. Sleep duration was categorized into three groups: normal, short, and long (7.0-8.9, < 7.0, and ≥ 9.0 h/day). Continuous variables such as body mass index (BMI) and waist circumference were employed to

define central and general obesity, respectively. Central obesity was defined as a waist circumference ≥ 90 cm for men and ≥ 80 cm for women, and general obesity was defined as BMI ≥ 28 kg/m^2 [25]. Both waist circumference and BMI were measured by trained nurses, minimizing the potential for self-report bias. Common diseases were also considered covariates, as disease status might have influenced liver function. Common diseases included dyslipidemia, major cardiovascular diseases, hypertension and diabetes.

Assessment of healthy lifestyle score

A healthy lifestyle score was computed based on our previous study by Liang X et al. [26], where the development and validity of the index were extensively evaluated. According to previous studies, the health lifestyle score was developed based on a priori knowledge, combining the most influential lifestyle factors associated with the outcome using a binary scoring system [11, 27]. Therefore, a healthy lifestyle score was derived based on five factors associated with liver function parameters, including smoking [10], alcohol consumption [18], physical activity [19], central and general obesity [28, 29]. Participants received a score of one on each lifestyle factor, if they were non-smoking, non-alcohol use, physically active, non-central and non-general obesity and zero otherwise. A composite score (ranging from zero to five) was calculated by summing up the scores from these five factors, with a higher score indicating a healthier lifestyle.

Outcomes

The outcome variables included ALT, AST, TBil, and ALB.

Statistical analysis

Characteristics of the study participants were described based on the grouping of the HLI scores. For normally distributed continuous variables such as age, mean (standard deviation) was used to represent the data, and analysis of variance (ANOVA) was employed to compare differences among different groups of the population. Categorical variables were presented as frequencies (percentages), and the chi-square test was used to assess the differences among different HLI score groups. For pairwise comparisons following the ANOVA, the Tukey-Kramer method was used. For variables with non-normal distributions, the Kruskal-Wallis test was applied, and Dunn's test with a Bonferroni adjustment was used for post-hoc pairwise comparisons.

A multiple linear regression model with adjusted confounding factors was employed to analyze the association between the statistically significant lifestyle variables (smoking, alcohol consumption, physical activity, central obesity, and general obesity) as independent variables, and various liver function parameters (continuous variables) as dependent variables. This analysis considered confounding factors related to demographic and socioeconomic factors, as well as common diseases, yielding adjusted regression coefficients (β) and their corresponding 95% confidence intervals (CIs). Multicollinearity among the predictor variables was assessed using the variance inflation factor (VIF), with values below 10 indicating no significant multicollinearity in the model. Statistical analysis was conducted using Stata 15.0 software. A two-sided P value of < 0.05 was considered statistically significant.

Results

Of 10,413 participants from the Guangzhou Biobank Cohort Study enrolled from 2003 to 2008, after excluding those with liver disease or missing data on variables of interest (n = 1703), 8710 participants were included in the current study. Among these, 2469 (28.35%) were men and 6241 (71.65%) were women. The average age was 64.67 (standard deviation (SD) = 6.07) years for overall sample, with mean ages of 66.29 (SD = 5.82) years for men and 64.02 (SD = 6.04) years for women. Table 1 shows significant differences in the distribution of general demographic by health lifestyle scores (ranging from 0 to 1, 2, 3, 4, to 5). Higher HLI was associated female gender, younger age, higher education, never smoking status, never alcohol use, active physical activity, non-central obesity, non-general obesity, non-dyslipidemia, non-major cardiovascular diseases, non-hypertension and non-diabetes (P values ranging from < 0.001 to 0.020). No significant association with occupation and sleep duration was found (Table 1).

Table 2 shows that, after adjusting for sex, age, education, family income and comorbidities (dyslipidemia, major cardiovascular diseases, hypertension, and diabetes), compared to non-users, former and current alcohol drinkers had a higher ALT level by 2.41 IU/L (95% CI: 0.53, 4.29) and 1.17 IU/L (95% CI: 0.06, 2.28), respectively. Compared to active participants, participants with insufficient or moderate physical activity showed a 1.73 IU/L (95% CI: 0.71, 2.74) higher in ALT level. Those with central obesity showed a 4.98 IU/L (95% CI: 3.92, 6.04) higher in ALT level compared to participants with normal waist circumference. Similarly, participants with general obesity showed a higher ALT level by 4.76 IU/L (95% CI: 3.56, 5.96) compared to those with normal weight.

Furthermore, alcohol drinkers showed a 1.75 IU/L (95% CI: 0.56, 1.84) higher in AST level compared to non-users. Drinkers showed a higher AST level by 0.85 IU/L (95% CI: 0.19, 1.52) compared to non-drinkers. Participants with insufficient or moderate physical activity showed a 1.12 IU/L (95% CI: 0.66, 1.57) higher in AST level compared to active participants. Those with central

Table 1 Basic characteristics by healthy lifestyle index (HLI) groups in 8710 participants of the Guangzhou biobank cohort study

	Healthy Lifestyle Index ζ					*P* value
	0–1	2	3	4	5	
Sex, N (%)						< 0.001
Women	48 (30.00)	439 (50.69)	1206 (65.34)	2515 (76.03)	1791 (82.92)	
Men	112 (70.00)	427 (49.31)	768 (34.66)	793 (23.97)	369 (17.08)	
Age, years, mean ± SD	65.90 ± 5.64	65.74 ± 6.13	65.27 ± 6.11	64.68 ± 6.03	63.53 ± 5.88	< 0.001
Education, N (%)						< 0.001
Primary or below	87 (54.38)	447 (53.93)	1206 (54.42)	1749 (52.87)	1019 (47.18)	
Secondary	59 (36.88)	314 (36.26)	848 (38.27)	1261 (38.12)	966 (44.72)	
College or above	14 (8.75)	85 (9.82)	162 (7.31)	298 (9.01)	175 (8.10)	
Occupation, N (%)						0.470
Manual	100 (6250)	545 (62.93)	1455 (65.66)	2174 (65.72)	1397 (64.68)	
Non-manual	54 (33.75)	282 (32.56)	655 (29.56)	973 (29.41)	644 (29.81)	
Others	6 (4.75)	39 (4.50)	106 (4.7)	161 (4.87)	119 (5.51)	
Family income, CNY/year, N (%)						0.007
< 10,000	10 (6.25)	65 (7.51)	157 (7.08)	247 (7.47)	164 (7.59)	
10,000–29,999	64 (40.00)	323 (37.30)	791 (35.69)	1116 (33.74)	684 (31.67)	
30,000–49,999	21 (13.13)	118 (13.63)	313 (14.12)	490 (14.81)	343 (15.88)	
≥ 50,000	23 (14.38)	77 (8.89)	185 (8.35)	360 (10.88)	224 (10.37)	
Don't know	42 (26.25)	283 (32.68)	770 (34.75)	1095 (33.10)	745 (34.49)	
Sleep duration, hours/day, N (%)						0.233
7.0-8.9	80 (50.00)	405 (46.77)	1065 (48.06)	1625 (49.12)	1041 (48.19)	
< 7.0	59 (36.88)	377 (43.53)	981 (44.27)	1417 (42.84)	935 (43.29)	
≥ 9.0	21 (13.13)	84 (9.70)	170 (7.67)	266 (8.04)	184 (8.52)	
Smoking status, N (%)						< 0.001
Never	26 (16.25)	394 (45.50)	1465 (66.11)	2860 (86.46)	2160 (100.00)	
Former	82 (51.25)	220 (25.40)	360 (16.25)	225 (6.80)	0 (0.00)	
Current	52 (32.50)	252 (29.10)	391 (17.64)	223 (6.74)	0 (0.00)	
Alcohol use, N (%)						< 0.001
Never	34 (21.25)	412 (47.58)	1615 (72.88)	3014 (91.11)	2160 (100.00)	
Former	29 (18.13)	72 (8.31)	58 (2.62)	26 (0.79)	0 (0.00)	
Current	97 (60.63)	382 (44.11)	543 (24.50)	268 (8.10)	0 (0.00)	
Physical activity, N (%)						< 0.001
Active	24 (15.00)	186 (21.48)	971 (43.82)	2184 (66.02)	2160 (100.00)	
Moderate to inactive	136 (85.00)	680 (78.52)	1245 (56.18)	1124 (56.18)	0 (0.00)	
Central obesity, N (%)						< 0.001
No	4 (2.50)	237 (27.37)	747 (33.71)	1879 (56.80)	2160 (100.00)	
Yes	156 (97.50)	629 (72.63)	1469 (66.29)	1429 (43.20)	0 (0.00)	
General obesity, N (%)						< 0.001
No	47 (29.38)	503 (58.08)	1850 (83.48)	3295 (99.61)	2160 (100.00)	
Yes	113 (70.62)	363 (41.92)	366 (16.52)	13 (0.39)	0 (0.00)	
Dyslipidemia, N (%)						< 0.001
No	68 (42.50)	411 (47.46)	1116 (50.36)	1699 (51.36)	1204 (55.62)	
Yes	92 (57.50)	455 (52.54)	1100 (49.64)	1609 (48.64)	956 (44.26)	
Major cardiovascular diseases, N (%)						< 0.001
No	143 (89.38)	807 (93.19)	2079 (93.82)	3110 (94.01)	2052 (95.00)	
Yes	17 (10.62)	59 (6.81)	137 (6.18)	198 (5.99)	108 (5.00)	
Hypertension, N (%)						0.020
No	54 (33.75)	358 (41.34)	1052 (47.47)	1748 (52.84)	1224 (56.67)	
Yes	106 (66.25)	508 (58.66)	1164 (52.53)	1560 (47.16)	936 (43.33)	
Diabetes, N (%)						< 0.001

Table 1 (continued)

	Healthy Lifestyle Index [ζ]					*P* value
	0–1	2	3	4	5	
No	118 (73.75)	734 (84.76)	1915 (86.42)	2922 (88.33)	1986 (91.94)	
Yes	42 (26.25)	132 (15.24)	301 (13.58)	386 (11.67)	174 (8.06)	

SD = standard deviation, CNY = Chinese yuan.

Results are presented as counts (%) or means ± standard deviations.

[ζ]: Healthy Lifestyle Index comprises five factors (non-smoking, non-alcohol use, active physical activity, non-central obesity, and non-general obesity), each contributing 1 point. The score ranges from 0 to 5, with higher scores indicating a healthier lifestyle.

Table 2 Association of lifestyle factors with liver function parameters in 8710 participants of the Guangzhou biobank cohort study

	Liver function parameters, adjusted β (95% CI) [†]			
	ALT, IU/L	AST, IU/L	TBil, μmol/L	ALB, IU/L
Smoking status				
Never	0.00	0.00	0.00	0.00
Former	0.35 (-0.77, 1.76)	0.29 (-0.50, 1.09)	-0.36 (-0.80, 0.08)	-0.29 (-0.61, 0.03)
Current	-1.32 (-2.56, -0.07) *	-0.99 (-1.77, -0.20) *	-1.33 (-1.77, -0.90) ***	-0.75 (-1.06, -0.43) ***
Alcohol use				
Never	0.00	0.00	0.00	0.00
Former	2.41 (0.53, 4.29) *	1.75 (0.56, 1.84) **	-0.08 (-0.74, 0.57)	0.34 (-0.14, 0.82)
Current	1.17 (0.06, 2.28) *	0.85 (0.19, 1.52) **	0.59 (0.20, 0.98) **	0.32 (0.03, 0.60) *
Physical activity				
Active	0.00	0.00	0.00	0.00
Moderate to inactive	1.73 (0.71, 2.74) **	1.12 (0.66, 1.57) ***	0.41 (0.06, 0.76) *	0.15 (-0.11, 0.40)
Central obesity				
No	0.00	0.00	0.00	0.00
Yes	4.98 (3.92, 6.04) ***	0.85 (0.19, 1.52) *	0.13 (-0.23, 0.50)	-0.15 (-0.42, 0.12)
General obesity				
No	0.00	0.00	0.00	0.00
Yes	4.76 (3.56, 5.96) ***	1.43 (0.68, 2.18) ***	0.09 (-0.33, 0.51)	-0.18 (-0.49, 0.12)

ALB = albumin, ALT = alanine aminotransferase, AST = aspartate aminotransferase, TBil = total bilirubin, CI = confidence interval.

[†]: Significant factors in the Table 1 were selected for analysis in this Table.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

obesity had a higher AST level by 0.85 IU/L (95% CI: 0.19, 1.52) compared to individuals with normal waist circumference. Similarly, participants with general obesity had a higher AST level by 1.43 IU/L (95% CI: 0.68, 2.18) compared to those with normal weight. Furthermore, alcohol drinkers showed a higher level of TBil by 0.59 IU/L (95% CI: 0.20, 0.98) compared to non-drinkers. Participants with insufficient or moderate physical activity showed a higher TBil level by 0.41 IU/L (95% CI: 0.06, 0.76) compared to active participants. Smokers had a lower ALB level by -0.75 IU/L (95% CI: -1.06, -0.43) compared to non-smokers (Table 2).

Table 3 shows that after adjusting for sex, age, education, family income, and comorbidities (dyslipidemia, major cardiovascular diseases, hypertension, and diabetes), those with healthy lifestyle scores of 1, 2, 3, 4, and 5 showed a decrease in ALT level of -5.85 IU/L (95% CI: -10.73, -0.97), -9.97 IU/L (95% CI: -14.53, -5.42), -11.34 IU/L (95% CI: -15.86, -6.82), -12.81 IU/L (95% CI: -17.33, -8.30), and -14.15 IU/L (95% CI: -18.68, -9.62), respectively (P for trend < 0.001). Additionally, participants with healthy lifestyle score of 1, 2, 3, 4, and 5, versus a score of 0, had a lower AST level by -1.82 IU/L (95% CI: -4.85, 1.21), -3.74 IU/L (95% CI: -6.57, -0.91), -4.47 IU/L (95% CI: -7.28, -1.66), -4.69 IU/L (95% CI: -7.49, -1.88), and – 4.75 IU/L (95% CI: -7.57, -1.94), respectively (P for trend < 0.001). Furthermore, for those with higher healthy lifestyle scores, an increasing trend in ALB level was observed (P for trend = 0.003).

Discussion

Our study, of a large sample and comprehensive adjustment for multiple confounding factors, showed significant associations between lifestyle factors and liver function parameters. Notably, alcohol consumption, insufficient physical activity, and central or general obesity were associated with higher ALT and AST levels. Additionally, a healthy lifestyle score including non-smoking, non-alcohol use, physically active, non-central and non-general obesity demonstrated a dose-response relationship with liver function parameters, showing lower ALT and AST levels and higher ALB levels as the

Table 3 Association of healthy lifestyle index with liver function parameters in 8710 participants of the Guangzhou biobank cohort study

	Healthy Lifestyle Index [ζ]						*P* for trend
	0	1	2	3	4	5	
ALT, IU/L							
Unadjusted Model	0.00	-7.14 (-12.11, -2.16) **	-12.04 (-16.67, -7.41) ***	-13.80 (-18.40, -9.21) ***	-15.50 (-20.08, – 10.91) ***	-16.97 (-21.57, -12.38) ***	< 0.001
Adjusted Model[†]	0.00	-5.85 (-10.73, -0.97) *	-9.97 (-14.53, -5.42) ***	-11.34 (-15.86, -6.82) ***	-12.81 (-17.33, -8.30) ***	-14.15 (-18.68, -9.62) ***	< 0.001
AST, IU/L							
Unadjusted Model	0.00	-2.03 (-5.06, 1.00)	-4.05 (-6.88, -1.22) **	-4.93 (-7.73, -2.12) **	-5.25 (-8.05, -2.46) **	-5.43 (-8.24, -2.63) ***	< 0.001
Adjusted Model[†]	0.00	-1.82 (-4.85, 1.21)	-3.74 (-6.57, -0.91) *	-4.47 (-7.28, -1.66) **	-4.69 (-7.49, -1.88) **	-4.75 (-7.57, -1.94) **	< 0.001
TBil, μmol/L							
Unadjusted Model	0.00	-1.39 (-3.11, 0.33)	-1.49 (-3.09, 0.12)	-1.97 (-3.56, -0.38) *	-1.82 (-3.41, -0.24) *	-1.63 (-3.22, -0.04)	0.852
Adjusted Model[†]	0.00	-1.06 (-2.75, 0.63)	-0.89 (-2.46, 0.69)	-1.12 (-2.69, 0.44)	-0.80 (-2.38, 0.76)	-0.51 (-2.07, 1.06)	< 0.001
ALB, IU/L							
Unadjusted Model	0.00	0.19 (-1.06, 1.44)	-0.20 (-1.37, 0.97)	0.01 (-1.15, 1.16)	0.14 (-1.02, 1.29)	0.23 (-0.92, 1.39)	< 0.001
Adjusted Model[†]	0.00	0.27 (-0.95, 1.50)	-0.05 (-1.19, 1.10)	0.17 (-0.97, 1.30)	0.28 (-0.85, 1.42)	0.33 (-0.81, 1.46)	0.003

Results are presented as β (95% CI).

[ζ]: Healthy Lifestyle Index comprises five factors (non-smoking, non-alcohol use, active physical activity, non-central obesity, and non-general obesity), each contributing 1 point. The score ranges from 0 to 5, with higher scores indicating a healthier lifestyle.

[†]: Significant factors in the Table 1 were selected for analysis in this Table.

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

score increased. Our findings highlight the important role of adopting a healthy lifestyle in maintaining optimal liver function. Implementing interventions to encourage these lifestyle changes could potentially reduce the burden of liver-related diseases and enhance overall population health.

Our study did not find statistically significant differences in serum liver function parameters (AST, ALT, TBil, ALB) between former smokers and never smokers. However, evidence suggests that smoking may have detrimental effects on various chronic liver diseases, including the development of hepatocellular carcinoma [30–32]. A population-based prospective cohort study in Korea showed higher levels of liver function parameters in heavy smokers (> 20 pack-years) compared to non-smokers [20]. Additionally, a meta-analysis indicated a positive association between smoking and non-alcoholic fatty liver disease [10], although no association was reported in another study [18]. As there is limited evidence on the association between smoking and serum liver enzyme levels, the underlying mechanisms of these associations remain to be elucidated.

In our study, compared to non-drinkers, former and current alcohol drinkers had higher levels of ALT, AST and TBil, which was consistent with results from previous studies [33–35]. Furthermore, we also found that, compared to active participants, those with insufficient or moderate physical activity showed higher levels of ALT and AST. Maintaining an active physical activity was strongly recommended for improving liver function in previous studies [36–38], which may also play a role through reducing obesity [8]. A previous study has reported an elevated risk of concurrent liver damage due to obesity and alcohol use in older adults [39]. Moreover, alcohol consumption, obesity, and metabolic syndrome were all positively associated with higher serum liver enzyme levels [39], suggesting potential synergistic effects of various lifestyle factors [6, 7].

Our study found that higher HLI was associated with lower ALT and AST, and higher ALB levels. A study on 9254 US adults aged about 50 years also showed that higher HLI scores (based on dietary patterns, body mass index, physical activity, smoking, and sleep duration) were associated with lower risks of non-alcoholic fatty liver disease and clinically significant fibrosis [40]. In addition, this US study also showed that higher HLI was associated with lower ALT levels but higher ALB levels. Improved adherence to a higher HLI appeared to correlate with liver parameter enhancement [40]. Moreover, a cross-sectional study of 240 adolescents showed a higher lifestyle score (incorporating dietary intake, moderate-to-vigorous physical activity, sedentary behavior, sleep duration, and BMI) was associated with lower hepatic steatosis index and fatty liver index values, suggesting that a healthy lifestyle during adolescence might contribute to metabolic dysfunction-associated steatotic liver disease (MASLD) prevention [41]. Our findings are in line with results of previous studies, suggesting that individuals adopting a healthy lifestyle tend to improve serum liver function.

Our results were generally consistent with previous studies on MASLD. For example, two studies on Chinese adults showed that high adherence to a healthy lifestyle, as indicated by a high HLI score, was associated with a lower risk of non-alcoholic fatty liver disease (NAFLD) [42, 43]. In our study, we comprehensively considered various factors, including demographic and socioeconomic factors, lifestyle factors and common diseases. We found that the HLI was significantly associated with indicators of liver function. Our findings highlight the significance of maintaining an optimal healthy lifestyle, which includes factors such as non-smoking, non-alcohol use, physically active, non-central and non-general obesity, in significantly reducing the risk of abnormal liver function.

Several limitations warrant consideration in interpreting the results of our study. Firstly, our investigation focused exclusively on non-genetic factors, thereby overlooking the potential influence of genetic variables, which may also play a pivotal role in the observed associations. Future studies that incorporate genetic factors could provide a more comprehensive understanding of the underlying mechanisms. Secondly, the cross-sectional design employed in our study precludes any definitive causal inferences. While we have identified associations between certain variables and outcomes, the temporal sequence and causality remain undetermined. To elucidate causative relationships, further prospective cohort studies or controlled clinical trials are warranted. The third limitation of our study is the lack of an independent validation cohort. The lack of an independent validation cohort limits the robustness of our findings and the generalizability of our results to other populations. Future research should aim to replicate these findings in external cohorts. Fourthly, although our study included a detailed assessment of alcohol consumption, including current frequency and quantity, information on lifetime changes in drinking patterns, such as alcohol use during youth or long-term changes in drinking behavior, was not available. Fifth, the analysis was based on baseline data collected approximately 20 years ago, and no follow-up data were included. However, given the relatively stable lifestyle factors in older adults, the lack of longitudinal data may not significantly affect the interpretation of the main findings. Finally, all participants were older Chinese people. The generalizability of the findings to other populations of younger age or different ethnic backgrounds may be limited, although there is no evidence to suggest that the potentially beneficial effects of HLI vary by age or ethnicity.

Conclusions

In conclusion, our study showed a significant association of healthy lifestyle with liver function parameters. Increasing the number of favorable lifestyle factors was linked to a reduced risk of abnormal liver function. Our findings indicate the value of promoting a healthy lifestyle to prevent abnormal liver function, potentially reducing liver disease-related morbidity and mortality.

Abbreviations

ALB	Albumin
ALT	Alanine aminotransferase
ANOVA	Analysis of variance
AST	Aspartate aminotransferase
BMI	Body mass index
CI	Confidence interval
GBCS	Guangzhou Biobank Cohort Study
HLI	Healthy Lifestyle Index
IPAQ-C	Chinese version of the International Physical Activity Questionnaire
MET	Metabolic equivalent task
MASLD	Metabolic dysfunction-associated steatotic liver disease
NAFLD	Non-alcoholic fatty liver disease
SD	Standard deviation
TBil	Total bilirubin

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Author contributions

LYS, TYL, LX, WSZ, and YLJ have substantial contributions to conception and design, acquisition of funding, data and interpretation of data; LYS and LX analyzed the data; LYS and TYL drafted the article; LX and WSZ revised it critically for important intellectual content. All authors read and approved the final manuscript.

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Data availability

Due to privacy or ethical restrictions, the data that support the findings will be made available on requests from the Guangzhou Biobank Cohort Study Data Access Committee (gbcsdata@hku.hk). The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Guangzhou Medical Ethics Committee of the Chinese Medical Association (IRB No. 20030210 and date of approval 10 February 2003). Informed consent was obtained from all participants involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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