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Longitudinal association between soft drink consumption and handgrip strength in adults: a prospective analysis from the Tianjin Chronic Low-Grade Systemic Inflammation and Health (TCLSIH) cohort study

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Abstract

Soft drink consumption has become a highly controversial public health issue. Given the pattern of consumption in China, sugar-sweetened beverage is the main type of soft drink consumed. Due to containing high levels of fructose, a soft drink may have a deleterious effect on handgrip strength (HGS) due to oxidative stress, inflammation and insulin resistance. However, few studies show an association between soft drink consumption and HGS in adults. We aimed to investigate the association between soft drink consumption and longitudinal changes in HGS among a Chinese adult population. A longitudinal population-based cohort study (5-year follow-up, median: 3·66 years) was conducted in Tianjin, China. A total of 11 125 participants (56·7 % men) were enrolled. HGS was measured using a handheld digital dynamometer. Soft drink consumption (mainly sugar-containing carbonated beverages) was measured at baseline using a validated FFQ. ANCOVA was used to evaluate the association between soft drink consumption and annual change in HGS or weight-adjusted HGS. After adjusting for multiple confounding factors, the least square means (95 % CI) of annual change in HGS across soft drink consumption frequencies were −0·70 (−2·49, 1·09) for rarely drinks, −0·82 (−2·62, 0·97) for < 1 cup/week and −0·86 (−2·66, 0·93) for ≥ 1 cup/week ($P_{for\ trend} < 0·05$). Likewise, a similar association was observed between soft drink consumption and annual change in weight-adjusted HGS. The results indicate that higher soft drink consumption was associated with faster HGS decline in Chinese adults.

Keywords: **Soft drink consumption: Handgrip strength: Cohort studies: Fructose**

Loss of handgrip strength (HGS) with ageing is a natural consequence[1]. HGS is a marker of concurrent overall skeletal muscle strength, bone mineral density and risk for cognitive impairment, diabetes and so on[2]. Meanwhile, epidemiological studies have shown that low HGS indicates a higher risk of functional limitations, disability and all-cause mortality in the

Abbreviations: DBP, diastolic blood pressure; FBG, fasting blood glucose; HGS, handgrip strength; MET, metabolic equivalent; PA, physical activity; SBP, systolic blood pressure; TC, total cholesterol; WC, waist circumference.

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future[3]. Therefore, identifying modifiable risk factors that reduce HGS loss is critical to advocating for appropriate prevention strategies.

Soft drink consumption has become a highly controversial public health issue given their widespread availability, which is rapidly increasing. Based on the annual report of the British Soft Drink Association, the overall consumption of soft drinks in the UK has also increased since 2010, rising to 13·3 billion litres by 2015[4–6]. Likewise, from 2000 to 2010, the total energy per capita of soft drinks in China has increased considerably by 215 % and 147 % for two large beverage companies, respectively[7]. In the past decades, sugar-sweetened beverages were the main type of soft drink consumed in China[8,9]. Thus, soft drinks in China contain large amounts of added sugars, especially fructose[10,11]. Compelling evidence has shown that dietary fructose induces oxidative stress, inflammation[12] and insulin resistance[13], thereby accelerating the loss of HGS[14,15]. Based on the above context, it is conceivable that soft drink consumption may accelerate age-related HGS loss.

Studies on the association between soft drink consumption and HGS are still limited. To our knowledge, only one cross-sectional study of ours has shown that higher consumption of soft drinks was significantly associated with lower HGS in Chinese middle-aged and older adults[16]. As cross-sectional studies may not determine the time sequence of the association, additional prospective studies are needed to confirm this association. Thus, we designed a longitudinal study to explore the association between soft drink consumption and HGS in a large-scale adult population.

Methods

Study population

The Tianjin Chronic Low-Grade Systemic Inflammation and Health cohort study, which began in 2007, is a multipurpose dynamic prospective cohort study designed to explore the association between diet and health-related outcomes among adults in Tianjin, China. The study recruited men and women who were 18 years and older living in Tianjin, China, for at least 5 years. They all had received health examinations and completed lifestyle questionnaires and physical performance tests. All measurements were undertaken on the same occasion by trained researchers or professional doctors.

The participant selection process is depicted in Fig. 1. During the period 2013–2018 at Tianjin Chronic Low-Grade Systemic Inflammation and Health, 12 516 participants aged 18 years and older completed baseline questionnaires (lifestyle factors), health screenings (blood tests, real-time abdominal ultrasound, etc.) and two or more times HGS measurements. Participants with missing data/extreme energy were excluded (*n* 804). Then we have excluded those participants with a history of CVD (*n* 497) and cancer (*n* 90). The final cohort analysis included 11 125 participants. The protocol of this study was approved by the Institutional Review Board of Tianjin Medical University (reference no: TMUhMEC 201430). Written informed consent was obtained from all the participants.

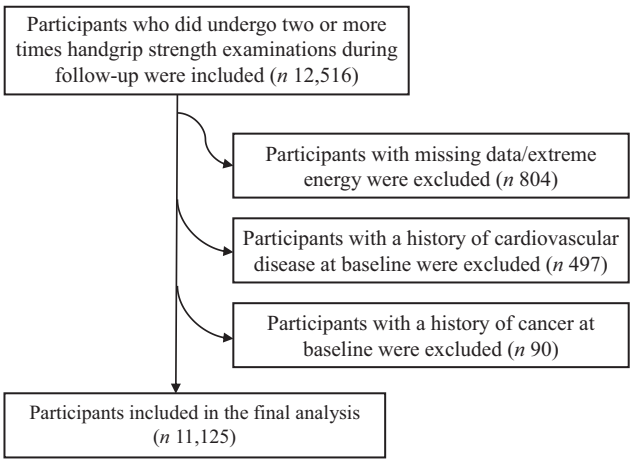

Fig. 1. Flow diagram showing the selection of the study population.

Measurement of handgrip strength

HGS was measured by trained assessors using a handheld dynamometer (EH101; CAMRY) (range 0–90 kg; accuracy 0·1 kg). Participants were instructed to stand upright and hold the dynamometer beside, but not against their body. Participants performed two trials for each hand alternatively with maximum force, always starting with the right hand. The maximum value was used for the study. Weight-adjusted HGS (kg/kg) was also calculated due to the effect of body weight on HGS[17]. And weight-adjusted HGS has been used in our previous studies[18,19]. Annual change in HGS (kg/year) was calculated by subtracting baseline HGS from the follow-up HGS, divided by the follow-up time (years). Annual change in weight-adjusted HGS (kg/kg per year) was calculated by subtracting baseline weight-adjusted HGS from the follow-up weight-adjusted HGS, divided by the follow-up time (years). The test variability for voluntary force in the same participant was below 5 %.

In the secondary analysis, low HGS was defined as being below the 20th percentile of HGS in the study population (< 38·25 kg for men and < 22·40 kg for women) according to the recommendations of the Asian Working Group for Sarcopenia[20]. These cut-off points are consistent with our previous paper[18].

Dietary assessment and soft drink consumption

Participants were asked to complete an FFQ that included 100 food items (the initial version of the FFQ included eight-one food items) including common foods and beverages consumed in the Tianjin population. The FFQ measured the foods and beverages intake of the participants over the previous 1 month before the physical examination. In the FFQ, participants reported the frequency of foods they consumed from seven frequency categories from 'almost never eat' to 'twice or more per d' and beverages they consumed from eight frequency categories from 'almost never drink' to 'four or more cups per d'. Generally, a soft drink includes sugar-sweetened soft drink and artificially sweetened soft drink[21]. However, according to the 2010–2015 national survey data, artificially sweetened soft drinks were generally less common in China[8,9]. Therefore, similar to our previous study[22], we did not assess sugar-sweetened soft drink

and artificially sweetened soft drink separately in this study. In the study, sugar-sweetened carbonated beverages were the major type of soft drink (such as Coke, Pepsi, Sprite or other carbonated beverages). In this study, soft drink did not include other beverages such as tea, coffee and fruit/vegetable juices. The volume of a typical cup of drink is 230 ml for men and 200 ml for women. As most people in China rarely consume soft drink[8], the participants were divided into three groups according to the frequency of soft drink consumption for analysis: 'rarely drinks', '< 1 cup/week' and '≥ 1 cup/week'. The three distinct categories given contain a considerable number of participants.

In a subsample of the Tianjin Chronic Low-Grade Systemic Inflammation and Health study (n 150), the reproducibility and validity of the FFQ were assessed by comparing data from two FFQ 3 months apart and four 4-d weighed diet records (once a son, 3 months apart). Spearman rank correlation coefficients between the two FFQ were 0·68 for total energy, 0·62–0·79 for food items (e.g. vegetables, fruits, coarse cereals, meat and beverages) and 0·75 for soft drink. Spearman correlation coefficients between the FFQ and dietary records were 0·49 for total energy, 0·35–0·54 for nutrients and 0·68 for soft drink.

Total energy intake was obtained by connecting information from the FFQ to the Chinese Food Composition Table. Factor analysis (principal component analysis) was conducted to derive dietary patterns using seventy-four food items (excluding all beverages, including green tea, oolong tea, red tea, coffee, juice and jasmine tea consumption) (in g/d). Varimax rotation was applied for greater interpretability. In all, three factors were retained based on the eigenvalues (> 1·5), scree plot, greater interpretability of factors and percentage of variance explained by the factors. The top fifteen food items of each pattern were considered to be the main contributors to the dietary pattern. Three dietary patterns were identified by factor analysis in the study. 'Sweet' dietary pattern was defined as a higher factor loading of strawberry, kiwi fruit, persimmon, sweets, candied fruits, cakes, pineapple, cookies and ice cream. 'Vegetable' dietary pattern was defined as a higher factor loading of celery, Chinese cabbage, cucumber, pumpkin, carrot, green vegetable, eggplant and raw vegetables. 'Animal food' dietary pattern was defined as higher factor loading of animal organs, animal blood, preserved egg, sausage, instant noodles and seafood.

Assessment of covariates

A self-administered questionnaire was used to collect data on demographics (age, sex, education level, employment and monthly household income), smoking status, alcohol drinking status and personal and family history of disease. Height and weight are measured by trained staff according to a standard protocol. The readings for height and weight are accurate to 0·1 cm and 0·1 kg, respectively. BMI is calculated by dividing weight in kilograms by the square of height. Physical activity was assessed using the short form of the validated 7-d International Physical Activity Questionnaire, expressed in metabolic equivalent (MET) hours per week. Depressive symptoms were assessed by the Chinese version of the Zung Self-Rating Depression Scale.

Laboratory tests included fasting blood glucose, TAG, total cholesterol, LDL-cholesterol and HDL-cholesterol, all performed from a fasting blood sample at baseline. Diabetes is defined as fasting blood glucose ≥ 7·0 mmol/l or blood glucose ≥ 11·1 mmol/l after 2 h of oral glucose tolerance test or self-reported history of diabetes[23]. Hyperlipidaemia was defined as an increase in lipid concentrations (total cholesterol ≥ 5·17 mmol/l, TAG ≥ 1·7 mmol/l or LDL-cholesterol ≥ 3·37 mmol/l) or the use of lipid-lowering drugs. Blood pressure was measured from the right upper arm using a TM-2655 oscilloscope (A&D). Hypertension was determined as a systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg or a history of hypertension or taking antihypertensive medication[24].

Statistical analyses

The distributions of all continuous variables were tested by the one-sample Kolmogorov–Smirnov test ($n \geq 2000$). Due to skewed distributions, descriptive data are expressed as medians (25th, 75th percentile) for continuous variables and as percentages for categorical variables.

The annual change in HGS (kg/year) and annual change in weight-adjusted HGS (kg/kg per year) were used as dependent variables, and the frequency of soft drink consumption was used as an independent variable. ANCOVA was used to assess all P values for linear trends of the association between frequency of soft drink consumption and annual change in HGS (kg/year)/annual change in weight-adjusted HGS (kg/kg per year). Results from ANCOVA were presented as least square means and corresponding 95 % CI. Three models were fitted in our analysis. Model 1 was an unadjusted model. Model 2 was adjusted for baseline age (years), sex (men or women) and BMI (kg/m^2). Model 3 was further adjusted for smoking status (current, former or never), alcohol drinking status (everyday drinker, sometime drinker, ex-drinker or non-drinker), education level (college graduate or not), employment (managers, professionals or other), monthly household income (< or ≥ 10 000 yuan), physical activity (MET-h/week), total energy intake (kcal/d), family history of diseases (including CVD, hypertension, hyperlipidaemia and diabetes), hypertension, hyperlipidaemia, diabetes, depressive symptoms (< or ≥ 45 score), sweet dietary pattern, vegetable dietary pattern, animal food dietary pattern and baseline HGS when analysing annual change in HGS or baseline weight-adjusted HGS when analysing annual change in weight-adjusted HGS. Covariates included in the adjusted models were selected based on previous knowledge using a directed acyclic graph (online Supplementary Fig. S1). Multicollinearity among covariates in the fully adjusted model was assessed using variance inflation factors. All variance inflation factors were less than 3·00, showing low collinearity.

To further validate our results, we performed sensitivity analysis by exploring the prospective association between the frequency of soft drink consumption and the risk of incident low HGS. Multivariable Cox proportional hazards models were conducted to estimate hazard ratios of low HGS on the frequency of soft drink consumption, with adjusting for the same variables in model 3. Furthermore, we conducted an

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analysis of the association between the intake of soft drink and annual change in HGS/weight-adjusted HGS. To correct for the potential measurement error, total soft drink intake was adjusted for total energy intake based on the nutrient density method and expressed in ml per 1000 kcal per d. For further analysis, the energy-adjusted soft drink intake was divided into three levels: because 54·9 % of the participants 'almost never' consumed soft drink, we considered this portion of soft drink intake as equal to '0' (ml per 1000 kcal per d) and defined it as the reference (level 1), and we additionally classified the remaining soft drink intake, which was more than '0' into halves (the lower half: level 2 and the upper half: level 3). All statistical analyses were conducted using SAS software version 9.4 (SAS Institute Inc.). All tests were two-sided, and $P < 0{\cdot}05$ was regarded as statistically significant.

Results

Table 1 shows the baseline characteristics of the study participants according to the frequency of soft drink consumption. In this study, the number of participants was 11 125, of which 56·7 % were men. Compared with those consuming soft drink rarely, those consuming ≥ 1 cup/week were younger, were more likely to be men and had higher BMI, waist circumference, total cholesterol, LDL-cholesterol and total energy intake but lower HDL-cholesterol, diastolic blood pressure and baseline HGS. They were also more likely to be current smokers, sometime alcohol-drinkers and professionals, were more likely to have depressive symptoms and were less likely to have hyperlipidaemia and diabetes.

Table 2 shows the associations between the frequency of soft drink consumption and annual change in HGS or weight-adjusted HGS. Only in model 3, a higher frequency of soft drink consumption was associated with a larger decline in HGS and weight-adjusted HGS. The least square means (95 % CI) of annual change in HGS across frequencies of soft drink consumption were −0·70 (−2·49, 1·09) kg for rarely drinks, −0·82 (−2·62, 0·97) kg for < 1 cup/week and −0·86 (−2·66, 0·93) kg for ≥ 1 cup/week ($P_{\text{for trend}} < 0{\cdot}05$). A similar association was observed between soft drink consumption and annual change in weight-adjusted HGS ($P_{\text{for trend}} < 0{\cdot}001$).

In sensitivity analyses, Fig. 2 shows the association between soft drink consumption and the risk of low HGS. Compared with participants consuming rarely soft drink, the adjusted hazard ratios (95 % CI) were 1·20 (1·02, 1·41) for participants consuming soft drink < 1 cup/week, and 1·23 (1·05, 1·44) for participants consuming soft drink ≥ 1 cup/week ($P_{\text{for trend}} < 0{\cdot}01$). Likewise, the significant association was similar when soft drink consumption was grouped according to specific intake levels (online Supplementary Table 2).

Discussion

To the best of our knowledge, this is the first large-scale longitudinal study to investigate the association between soft drink consumption and annual change in HGS/weight-adjusted HGS in the general population. After adjustment for potential confounding factors, the results indicated that higher soft drink consumption was significantly associated with the decline of HGS/weight-adjusted HGS in the total population.

In our analysis, we adjusted for a variety of potential confounding factors. First, some studies have suggested that HGS is associated with sex[25], age[26] and BMI[27]. We adjusted for the three confounders in model 2. In model 2, we observed that soft drink consumption was not significantly associated with annual change in HGS/weight-adjusted HGS. Second, several studies have shown that HGS is associated with lifestyle factors[28], socio-economic status[29], multiple diseases[29,30] and diet factors[31]. Therefore, we further adjusted for smoking status, drinking status, physical activity, household income, employment status, educational levels, family history of diseases (including CVD, hypertension, hyperlipidaemia and diabetes), depressive symptoms, hypertension, hyperlipidaemia, diabetes, dietary patterns and baseline HGS when analysing annual change in HGS or baseline weight-adjusted HGS when analysing annual change in weight-adjusted HGS in model 3. After adjusting for these factors, pronounced associations between soft drink consumption and annual change in HGS/weight-adjusted HGS were observed.

A previous cross-sectional study[16] of ours showed that a higher frequency of soft drink consumption was significantly associated with lower HGS in aged 40 years and older Chinese. However, the cross-sectional study may not determine the time sequence of the association. Our present cohort study has given prospective evidence that higher soft drink consumption was associated with a faster decline in HGS in a large range of adults.

The following several potential biological mechanisms may explain the association between soft drink consumption and HGS. Soft drink in China contains high amounts of fructose[10,32]. First, chronic fructose consumption causes oxidative stress[12], compelling evidence indicates that increased oxidative stress is associated with age-related losses of skeletal muscle mass and function[33]. Oxidative stress accelerates the apoptosis of muscle cells due to the synthesis of faulty proteins, oxidised lipids and mtDNA mutations[34]. Second, systematic inflammation by fructose is also a factor in the loss of HGS[12]. Inflammatory mediators directly reduce muscle mass and strength because pro-inflammatory cytokines, particularly TNFα and IL-6, stimulate proteolysis throughout the ubiquitin–proteasome-dependent system[35]. Indeed, Marjolein Visser's study indicated that an increase in IL-6 or TNFα value both causes a reduction of muscle mass and strength[36]. Finally, the fructose in soft drink could directly induce insulin resistance through the insulin signalling pathway and indirectly by lipogenesis, decreasing mitochondrial fatty acid oxidation, endoplasmic reticulum stress and liver inflammation[13]. Insulin resistance blunts muscle protein synthesis by reducing secreting insulin-like growth factor 1[14].

There are several strengths in this study. First, it is the first to investigate the association between soft drink consumption and annual change of HGS among a large-scale adult population. Second, the study has detailed measurements of diet and lifestyle

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Table 1. Baseline characteristics of participants according to the frequency of soft drink consumption (*n* 11 125)*

Characteristics	Frequency of soft drink consumption: Rarely drinks %	Rarely drinks: Least square geometric means	Rarely drinks: 95 % CI	< 1 cup/week %	< 1 cup/week: Least square geometric means	< 1 cup/week: 95 % CI	≥ 1 cup/week %	≥ 1 cup/week: Least square geometric means	≥ 1 cup/week: 95 % CI	$P_{for\ trend}$†
Participants, *n*		5982			2091			3052		–
Age (years)		43·7	43·5, 44·0		37·9	37·5, 38·3		35·0	34·6, 35·3	< 0·01
Sex (men, %)	52·4			57·3			64·7			< 0·01
BMI (kg/m^2)		24·4	24·4, 24·5		24·5	24·4, 24·7		24·7	24·6, 24·8	< 0·01
WC (cm)		81·2	80·9, 81·4		81·3	80·9, 81·7		81·8	81·4, 82·1	< 0·01
TC (mmol/l)		4·69	4·67, 4·72		4·73	4·69, 4·77		4·79	4·75, 4·82	< 0·01
TAG (mmol/l)		1·32	1·30, 1·35		1·32	1·27, 1·36		1·37	1·33, 1·40	0·08
LDL-cholesterol (mmol/l)		2·73	2·71, 2·75		2·78	2·75, 2·82		2·83	2·80, 2·86	< 0·01
HDL-cholesterol (mmol/l)		1·41	1·40, 1·42		1·39	1·38, 1·41		1·38	1·36, 1·39	< 0·01
FBG (mmol/l)		5·14	5·11, 5·16		5·09	5·05, 5·13		5·12	5·08, 5·15	0·31
SBP (mmHg)		119·0	118·7, 119·4		118·3	117·6, 118·9		118·5	118·0, 119·1	0·15
DBP (mmHg)		75·5	75·2, 75·7		75·5	75·1, 75·9		75·0	74·6, 75·4	< 0·05
PA (MET-h/week)		20·6	19·7, 21·4		18·2	16·7, 19·6		19·3	18·1, 20·6	0·12
Total energy intake (kcal/d)		2383·6	2359·2, 2408·1		2322·1	2281·5, 2362·6		2572·6	2537·6, 2607·6	< 0·01
Smoking status (%)										
Current smoker	17·4			17·8			23·6			< 0·01
Ex-smoker	6·53			5·15			4·37			0·11
Non-smoker	76·0			77·1			72·0			< 0·01
Alcohol drinking status (%)										
Everyday	4·44			2·62			2·84			0·58
Sometime	56·4			62·9			65·2			< 0·01
Ex-drinker	9·45			8·94			8·02			< 0·01
Non-drinker	29·7			25·5			24·0			< 0·05
Education level (≥ college, %)	71·6			82·8			83·9			0·29
Occupation (%)										
Managers	51·1			51·5			49·8			0·20
Professionals	15·9			18·8			21·5			< 0·01
Other	33·0			29·8			28·6			0·07
Monthly household income (≥ 10 000 yuan, %)	41·6			42·7			43·9			0·89
Depressive symptoms (score ≥ 45, %)	14·3			15·5			19·0			< 0·01
Hypertension (%)	25·8			18·8			17·9			0·35
Hyperlipidaemia (%)	46·4			42·1			42·1			< 0·01
Diabetes (%)	7·54			2·92			2·62			< 0·01
Family history of disease (%)										
CVD	37·4			34·2			27·4			0·58
Hypertension	56·0			54·0			51·3			< 0·05
Hyperlipidaemia	0·53			0·57			0·49			0·45
Diabetes	28·9			28·7			26·4			0·84
Baseline handgrip strength (kg)		35·1	34·9, 35·2		35·2	34·9, 35·4		34·8	34·5, 35	< 0·05

WC, waist circumference; TC, total cholesterol; FBG, fasting blood glucose; SBP, systolic blood pressure; DBP, diastolic blood pressure; MET, metabolic equivalent; PA, physical activity.
* Continuous variables are expressed as least square geometric means (95 % CI) and categorical variables are expressed as percentages.
† ANCOVA or logistic regression analysis.

Table 2. Association of soft drink consumption with annual change in handgrip strength (HGS) or weight-adjusted HGS (*n* 11 125)

	Frequency of soft drink consumption						
	Rarely drinks		< 1 cup/week		≥ 1 cup/week		
	Least square mean	95 %	Least square mean	95 %	Least square mean	95 %	$P_{for\ trend}$*
No. of subjects (*n* 11 125)	5982		2091		3052		–
Person-years	21 385·0		7770·0		11 531·0		–
Means of person-years	3·57		3·72		3·78		–
Annual change in HGS (kg per year)							
Crude	0·05	–0·03, 0·13†	0·00	–0·13, 0·14	0·09	–0·02, 0·20	0·53
Model 1‡	0·07	–0·01, 0·15	–0·04	–0·17, 0·10	0·01	–0·11, 0·13	0·42
Model 2§	–0·70	–2·49, 1·09	–0·82	–2·62, 0·97	–0·86	–2·66, 0·93	< 0·05
Annual change in weight-adjusted HGS (kg/kg per year)							
Crude	–0·0005	–0·0017, 0·0007	–0·0020	–0·0040, 0·0000	–0·0017	–0·0034, –0·0001	0·23
Model 1‡	–0·0004	–0·0016, 0·0008	–0·0021	–0·0041, 0·0000	–0·0021	–0·0038, –0·0003	0·14
Model 2§	–0·0024	–0·0285, 0·0237	–0·0043	–0·0304, 0·0219	–0·0063	–0·0325, 0·0198	< 0·01

* ANCOVA.
† Adjusted least square mean (95 % CI) (all such values).
‡ Adjusted for age, sex and BMI.
§ Additional adjusted smoking status (current, former or never), alcohol drinking status (everyday drinker, sometime drinker, ex-drinker or non-drinker), education level (college graduate or not), employment (managers, professionals or other), monthly household income (< or ≥ 10 000 yuan), physical activity (MET-h/week), family history of disease (including CVD, hypertension, hyperlipidaemia and diabetes (each yes or no)), depressive symptoms (< or ≥ 45 score), hypertension (yes or no), hyperlipidaemia (yes or no), diabetes (yes or no), total energy intake (kcal/d), sweet dietary pattern, vegetable dietary pattern, animal food dietary pattern and baseline HGS when analysing annual change in HGS or baseline weight-adjusted HGS when analysing annual change in weight-adjusted HGS.

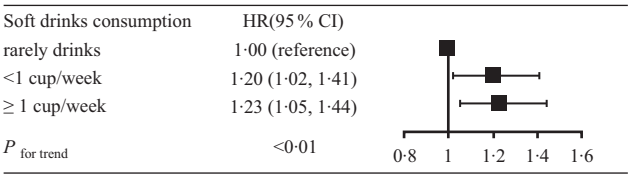

Fig. 2. Adjusted association between soft drink consumption and risk of incident low HGS. Analyses adjusted for baseline age, sex and BMI, smoking status (current, former or never), alcohol drinking status (everyday drinker, sometime drinker, ex-drinker or non-drinker), education level (college graduate or not), employment (managers, professionals or other), monthly household income (< or ≥ 10 000 yuan), physical activity (MET-h/week), family history of disease (including CVD, hypertension, hyperlipidaemia and diabetes (each yes or no)), depressive symptoms (< or ≥ 45 score), hypertension (yes or no), hyperlipidaemia (yes or no), diabetes (yes or no), total energy intake (kcal/d), sweet dietary pattern, vegetable dietary pattern, animal food dietary pattern and baseline handgrip strength. HGS, handgrip strength; MET, metabolic equivalent.

factors and a large sample size. Finally, the study also adjusted a large number of potential confounders to make the results more realistic and reliable.

However, some limitations need to be pointed out. First, not all types of soft drink data were collected in our study, such as sugar-sweetened soft drink and artificially sweetened soft drink. Thus, we are unable to separately analyse how other soft drinks influence carotid atherosclerosis. However, data from national surveys indicate that consumption of artificially sweetened soft drink was low in our study population[8,9]. Second, soft drink consumption was collected at baseline and might not represent the long-term state before the results. Third, the proportion of the three soft drink consumption of participants included was 53·8 % for rarely drinks, 18·8 % for < 1 cup/week and 27·4 % for ≥ 1 cup/week, respectively, while the proportion of participants excluded was 65·4 % for rarely drinks, 12·9 % for < 1 cup/week and 21·7 % for ≥ 1 cup/week, respectively. The proportion of soft drink consumption of participants included and excluded was significantly different ($P < 0·05$). Moreover, participants who were excluded were typically in poorer physical condition compared with those who were included. Meanwhile, the study was conducted only in Tianjin, China. Therefore, the included study population limits the generalisability of our findings to external populations. However, the issue of sample representativeness should not be a key concern in exposure-outcome studies[37]. Finally, although our study adjusted a number of confounders, we still could not exclude the possibility that there are other relevant factors that we have not fully obtained.

Conclusions

In conclusion, the longitudinal study suggests that higher soft drink consumption was associated with a greater decline in weight-adjusted HGS in the Chinese adult population. Further studies are needed to confirm this finding in different populations.

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T. L. and K. N. had full access to all the data in the study and took responsibility for the integrity of the data and the accuracy of the data analysis.

T. L., G. M., Z. F. and K. N. designed research; T. L., G. M., Z. F and K. N. conducted research; T. L. analysed data; and T. L. wrote the paper; S. Q. provide valuable insights, data analysis, and offering critical feedback during revision period. K. N. had primary responsibility for the final content. All authors read and approved the final manuscript.

None of the authors had a conflict of interest to disclose.

The data for Tianjin Chronic Low-Grade Systemic Inflammation and Health cohort cannot be made publicly available because public availability would compromise participant privacy. For data access, researchers can contact the Nutritional Epidemiology Institute and School of Public Health, Tianjin Medical University, Tianjin, China (Email address: nkj0809@gmail.com or niukaijun@tmu.edu.cn).

Data described in the manuscript, code book and analytic code will be made publicly and freely available without restriction at https://upload.umin.ac.jp/cgi-open-bin/ctr_e/ctr_view.cgi?recptno=R000031137.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114523002817

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