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Effect of breakfast frequency on cardiovascular disease risk factors: A 3-year prospective cohort study

Wu Danping[1], Hao Zongji[2,*], Tang Chuan[3]

[1]Physical Education Teaching and Research Group, Chengdu Caotang Primary School West Campus, Chengdu, China
[2]Physical Education Teaching and Research Group, Chongqing Liangjiang Yucai Middle School, Chongqing, China
[3]Chengdu Experimental Primary School Zhanqi Branch, Chengdu, China
[*]Corresponding author: 1263392611@qq.com

Abstract: *Low breakfast frequency is a recognized health risk factor. However, there is almost no epidemiological evidence to suggest a causal relationship between breakfast frequency and cardiovascular disease risk among middle school students. Therefore, we aim to investigate the relationship between breakfast frequency and cardiovascular disease risk among Chinese middle school students. A 3-year prospective cohort study was conducted among2622 Chinese middle school students. Breakfast frequency were assessed with a self-reported questionnaire. Analysis of covariance (ANCOVA)and logistic regression analysis was performed to testify the association between breakfast frequency(occasionally, Frequent, Daily) and cardiovascular disease risk factors. Research has found that in Chinese middle school students, a lower breakfast frequency is independently associated with abnormal blood lipids, blood sugar, blood pressure, and higher levels of inflammation. The research results indicate that a higher breakfast frequency may have potential beneficial effects on preventing cardiovascular disease.*

Keywords: *Cardiovascular disease risk factors, Breakfast Frequency, Chinese, middle school students, prospective cohort study*

1. Introduction

In recent years, the incidence of cardiovascular metabolic risk factors such as dyslipidemia, hypertension, and high levels of inflammation in adolescents worldwide has been on the rise.[1].The high-risk factors for cardiovascular disease not only affect children's physical health and quality of life, but also have adverse effects on adult health. The study found that coronary heart disease, hypertension, diabetes and atherosclerosis originated in childhood and adolescence, and their metabolic abnormalities caused pathological changes in cardiovascular and metabolic systems[2][3][4].

The unhealthy lifestyle and dietary habits formed during adolescence have been proven to be important factors affecting cardiovascular risk[5].Currently, more and more people skip breakfast, with 12% -34% of young people typically skipping breakfast. According to reports, skipping breakfast is associated with unhealthy behaviors such as reduced frequency of eating and reduced physical activity [6]. These behaviors can lead to cardiovascular metabolic risk factors. However, at present, research on breakfast frequency and cardiovascular risk factors mostly focuses on adults [7], while research on adolescents and children is relatively limited and mostly cross-sectional, making it difficult to confirm the causal relationship between breakfast frequency and cardiovascular risk factors. Based on this, a three-year prospective cohort study was designed for this study. Exploring the correlation between breakfast frequency and cardiovascular risk factors in adolescents, providing a basis for improving unhealthy behavior habits in adolescents and promoting physical and mental health.

2. Materials and Methods

2.1. Study Population

This prospective Cohort study was carried out in Chongqing Liangjiang Yucai Middle School. A total of 2303 middle school freshmen were included in the survey. The survey subjects are aged between 15

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and 16 years old, and they completed a self reporting questionnaire and a dietary history questionnaire in July 2020 and July 2023.From the total samples of 2303, we excluded 41 participants who did not participate in the 4th year questionnaire survey. Finally, the remaining2262 students were included in the analysis.

2.2. Measures

2.2.1. Assessment of Breakfast frequency

Breakfast frequency was determined by asking respondents the number of days per week on which they had consumed breakfast. The possible responses were no breakfast,1 time,2 times,3 times,4 times,5 times,6 times,and every day. Participants were categorized as either 'occasionally ' (0–3 days/week), 'frequently' (4–6 times a week) or 'daily' (7) breakfast consumers[8].

2.2.2. Assessment of Maximum oxygen uptake

Test the VO2max of the subjects using a 20 meter turn back run test. After preparing for the activity, the subjects will perform a turn back run on the starting line of the 20 meter turn back run, following Leger's load plan, from slow to fast within a 20 meter interval. When the subject cannot maintain the speed set by the music rhythm and stops moving midway, or if the subject cannot reach the 20m endpoint before the music starts for two consecutive times, the test is terminated and the maximum number of times the subject completes is recorded. During the test, all participants wore a Polar heart rate monitor (PolarV800 model) to monitor real-time heart rate changes. Calculate through formulasVO2max: MAS=8+0.5×grade,VO2max=31.025+3.238×MAS-3.248×Age+0.1536×MAS×Age[9].

2.2.3. Assessment of Blood pressure

This study used the HBP-1300 electronic blood pressure monitor (Omron, Japan) to measure the blood pressure of the subjects. The right upper arm blood pressure was measured twice, with a 1-minute interval, and the average of the two measurements was taken.

Hypertension is determined according to the high blood pressure screening threshold for children and adolescents aged 7-18 (WS/T610-2018), which means that systolic and/or diastolic blood pressure is ≥ 95 percentile of blood pressure in children of the same gender, age, and height[10].

2.2.4. Biochemical indicator detection

The subjects fasted for more than 12 hours before the physical examination. The peripheral blood of the left ring finger was collected by professional technicians and sent to the laboratory for biochemical testing within 4 hours. The detection indicators include fasting blood glucose (FPG), triglycerides (TG), and total cholesterol (TC).The diagnostic criteria for dyslipidemia refer to the Diagnostic Criteria for Hyperlipidemia in Children and Adolescents Aged 2-19 released by the National Cholesterol Education Program (NCEP) in the United States, with an abnormal standard of FPG ≥ 5.6 mmol/L.

According to the consensus of experts in the prevention and treatment of blood lipids in children and adolescents, the abnormal criteria for blood lipid evaluation are TG ≥ 1.70 mmol/L and TC ≥ 5.18 mmol/L[11].

2.2.5. Relevant Covariates

Demographic variables and lifestyle factors including sex, age, one child(yes or no), left-behind children(yes or no), body mass index (BMI) ,parent's education (High school degree or below, bachelor degree or above),marital status of parents(married, divorce or widowhood),sleep quality(good, bad),depression and anxiety were assessed using the Self-rating depression scale(SDS)[20].Evaluate the physical activity levels of team participants with the International Physical Activity Scale short version[21].The study used the Young Internet Addiction Scale to test the survey subjects[22].

2.2.6. Statistical Analysis

All categorical variables were presented as proportions and were compared by logistic regression analysis. Each body part with musculoskeletal pain was used as a dependent variable and categories of breakfast frequency were used as independent variables. Multiple logistic regression analysis was also used to examine the relationship between categories of breakfast frequency and each body part with musculoskeletal pain. Model 1 was the crude univariate model; Model 2 were adjusted for ages, sex, BMI, only on child, left-behind children, father education, mother education , parent's marital status ; Model 3 was additionally adjusted for demographic variables and lifestyle factors, as outlined above.

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Significance was set at $P < 0.05$ for two-sided tests. All tests were performed using IBM SPSS Statistics 24.0 software (IBM SPSS Inc., Chicago, IL, United States).

3. Results

According to the category of breakfast frequency, the baseline characteristics of participants are shown in Table 1.There are significant differences in physical activity and depression levels among subjects with different breakfast frequencies.

Table 1: The participants' characteristics, according to categories of Breakfast frequency.

Characteristic		Breakfast frequency			
		occasionally (N=416)	Frequent (N=1422)	Daily (N=424)	P for linear Trend[1]
Sex(Female)		44.2	44.5	44.1	0.997
Age (years)		15.56(15.54,15.67)	15.54(14.45,15.62)	15.54(15.47,15.62)	0.949
BMI(≥24)%		12.5	12.7	11.6	0.676
Only one child%		93	96.1	94.8	0.229
left-behind children		10.8	11.8	8.3	0.230
Parents marital status	first marriage	66.6	71.4	64.9	0.572
	divorce	16.8	11.0	14.9	0.408
	remarriage	16.6	17.5	20.3	0.161
Father education	High school degree or below	82.9	85	83.3	0.905
Mather education	High school degree or below	79.6	81.6	77.3	0.931
physical activity	low	21.6	30.7	5.9	0.646
	medium	38.7	32.1	37.3	0.97
	high	39.7	37.1	56.8	0.000
sleep quality(good)		82.5	84.7	86.1	0.146
Depression		12.7	10.5	7.5	0.01
internet addiction		17.1	17.4	15.1	0.442

[1]P for trends were assessed using multivariate logistic regression analyses. Significance of bold values is $P < 0.05$.

Table 2: Adjusted relationships between Breakfast frequency and the risk of musculoskeletal discomfort in different body parts at baseline.

	Total sample (n =2262)	Abnormal number of participants	Model 1 [a]	Model 2 [b]	Model 3 [c]
Blood sugar					
Daily	424	17	1.000(Reference)[d]	1.000(Reference)	1.000(Reference)
frequent	1422	92	1.656(0.976,2.811)	1.647(0.970,2.797)	1.487(0.865,2.556)
occasionally	416	39	2.477(1.378,4.453)	2.447(1.360,4.403)	2.575(1.246,4.087)
P for trend[e]			P<0.01	P<0.01	P<0.01
Blood pressure					
Daily	424	32	1.000(Reference)[d]	1.000(Reference)	1.000(Reference)
frequent	1422	136	1.295(0.867,1.935)	1.290(0.861,1.933)	1.370(0.907,2.068)
occasionally	416	42	1.376(0.850,2.226)	1.381(0.851,2.242)	1.467(0.899,2.394)
P for trend[e]			P<0.01	P<0.01	P<0.01
Blood fat					
Daily	424	89	1.000(Reference)[d]	1.000(Reference)	1.000(Reference)
frequent	1422	401	1.478(1.139,1.919)	1.475(1.135,1.917)	1.469(1.124,1.920)
Infrquent	416	144	1.993(1.463,2.714)	1.985(1.456,2.708)	1.981(1.448,2.711)
P for trend[e]			P<0.01	P<0.01	P<0.01

a Model 1: Crude; b Model 2: Adjusted for sex, age; Additionally adjusted for BMI, only on child (yes or no), left-behind children(yes or no),father education (High school degree or below, Bachelor degree or above), mother education (High school degree or below, Bachelor degree or above), parent's marital status (first marriage, divorce, remarriage) at baseline; c Model 3:sleep quality(good or bad),Depression

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level(continuous variables),physical activity(continuous variables),Internet Addiction(continuous variables) at baseline; d Adjusted data are expressed as odds ratio (95% confidence intervals); eP for trend were obtained using multivariate logistic regression analyses. Significance of bold values is P < 0.05.

Table 2 shows the significant relationships between breakfast frequency and risk of musculoskeletal pain in different body parts at baseline. Amongst all participants, abnormal blood lipids, blood glucose, and blood pressure were reported by 28% ,6.5% and 9.3%respectively at baseline.The ORs (95% CIs) for neck pain in each breakfast frequency category (Daily, Frequent, occasionally) in Model 3 were 1.000(Reference),1.487(0.865,2.556) and 2.575(1.246,4.087), respectively (P for trends: <0.01). The ORs (95% CIs) for shoulder pain in each Breakfast frequency category in Model 3 were 1.000(Reference),1.370(0.907,2.068)and 1.467(0.899,2.394) respectively (P for trends:P<0.01).The ORs (95% CIs) for elbow pain in each Breakfast frequency category in Model 3 were 1.000(Reference),1.469(1.124,1.920) and 1.981(1.448,2.711)respectively (P for trends: <0.01). In the baseline survey, the number of individuals who did not, Abnormal blood lipids, blood sugar, and blood pressure was 1627, 2146, and 1822, respectively.

Table 3 shows the relationship between blood lipids, blood pressure, blood glucose abnormalities, and breakfast frequency during the follow-up period. The number of participants with no Abnormal symptoms at baseline who developed Abnormal blood lipids, blood sugar, and blood pressure after two years were 463(28.5%),121(5.6%)and 230(12.6%), respectively. The ORs (95% CIs) for Blood sugar in each breakfast frequency category (Daily, Frequent, occasionally) in Model 3 were 1.000(Reference), 2.205(1.102,4.414),2.052(1.117,3.768), respectively (P for trends: = 0.022). The ORs (95% CIs) for Blood pressure in each Breakfast frequency category in Model 3 were 1.000(Reference), 0.976(0.65, 1.453), 2.140(1.385,3.307), respectively (P for trends: =0.025).The ORs (95% CIs) for blood lipids in each Breakfast frequency category in Model 3 were 1.000(Reference),1.823(1.336,2.487) and 1.911(1.307,2.794) respectively (P for trends: = 0.037).

Table 3: Adjusted relationships between Breakfast frequency and the risk of musculoskeletal discomfort in different body parts during the 3-year follow-up period.

	Total sample	Abnormal number of participants	Model 1 a	Model 2 b	Model 3 c
Blood sugar(n=2146)					
Daily	394	13	1.000(Reference)d	1.000(Reference)	1.000(Reference)
frequent	1274	83	2.017(1.112,3.659)	2.155(1.085,4.280)	2.205(1.102,4.414)
occasionally	394	25	2.153(1.085,4.272)	2.018(1.113,3.611)	2.052(1.117,3.768)
P for trende			P<0.01	P<0.01	0.022
Blood pressure(n=1822)					
Daily	429	37	1.000(Reference)d	1.000(Reference)	1.000(Reference)
frequent	1410	124	1.295(0.867,1.935)	1.020(0.692,1.502)	0.976(0.65,1.453)
occasionally	443	69	2.171(0.696,1.506)	2.181(1.420,3.351)	2.140(1.385,3.307)
P for trende			P<0.01	0.016	0.025
Blood fat(n=1627)					
Daily	399	65	1.000(Reference)d	1.000(Reference)	1.000(Reference)
frequent	1334	313	1.830(1.353,2.731)	1.818(1.343,2.462)	1.823(1.336,2.487)
occasionally	357	85	1.881(1.295,2.731)	1.900(1.306,2.764)	1.911(1.307,2.794)
P for trende			P<0.01	0.014	0.037

aModel 1: Crude; bModel 2: Adjusted for sex, age; Additionally adjusted for BMI, only on child (yes or no), left-behind children(yes or no),father education (High school degree or below,Bachelor degree or above), mother education (High school degree or below,Bachelor degree or above), parent's marital status (first marriage, divorce, remarriage) at baseline;c Model 3:sleep quality(good or bad),Depression level(continuous variables),physical activity(continuous variables),Internet Addiction(continuous variables) at baseline; d Adjusted data are expressed as odds ratio (95% confidence intervals); eP for trend were obtained using multivariate logistic regression analyses. Significance of bold values is P < 0.05.

Table 4 shows the relationship between breakfast frequency at baseline and changes in maximum oxygen uptake during the 3-year follow-up.After adjusting for all covariates, the Higher breakfast frequency the higher the improvement in Maximum oxygen uptake. In Model 3, the changes in maximum oxygen uptake in the breakfast frequency was -0.375(-0.527,-0.224) for occasionally,1.302(1.221,1.381) for frequent,2.813(2.666,2.959) for Daily,(P for trend:P<0.01);

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Table 4: Multivariable-adjusted relationships of Breakfast frequency with change in Maximal oxygen uptake during the 3-year follow-up period.

	N=2622	Number of participants	Model 2a	Model 2b	Model 3c
Maximal oxygen uptake	Daily	429	2.799(2.665,2.933)	2.809(2.675,2.943)	2.813(2.666,2.959)
	frequent	1410	1.294(1.222,1.366)	1.289(1.217,1.362)	1.302(1.221,1.381)
	occasionally	443	-0.294(-0.429,-0.160)	-0.289(-0.424,-0.155)	-0.375(-0.527,-0.224)
	P for trende		P<0.01	P<0.01	P<0.01

a Model 1: Crude; b Model 2: Adjusted for sex, age; Additionally adjusted for BMI, only on child (yes or no), left-behind children(yes or no),father education (High school degree or below, Bachelor degree or above), mother education (High school degree or below, Bachelor degree or above), parent's marital status (first marriage, divorce, remarriage) at baseline; c Model 3:sleep quality(good or bad),Depression level(continuous variables),physical activity(continuous variables),Internet Addiction(continuous variables) at baseline; d Adjusted data are expressed as odds ratio (95% confidence intervals); eP for trend were obtained using multivariate logistic regression analyses. Significance of bold values is P < 0.05.

Table 5: Multivariable-adjusted relationships of Breakfast frequency with Inflammation level during the 3-year follow-up period.

	n=2262	Number of participants	Model 2a	Model 2b	Model 3c
TNF-α(ng/L)	Daily	429	4.582(4.452,4.711)	4.588(4.457,4.718)	4.557(4.424,4.692)
	frequent	1410	4.629(4.558,4.700)	4.627(4.556,4.698)	4.638(4.566,4.709)
	occasionally	443	4.487(4.756,5.018)	4.889(4.757,5.020)	4.882(4.421,4.692)
	P for trende		0.001	0.001	0.001
IL-6(ng/L)	Daily	429	3.276(3.209,3.343)	3.271(3.204,3.337)	3.298(3.231,3.364)
	frequent	1410	3.412(3.376,3.448)	3.412(3.376,3.448)	3.404(3.367,3.440)
	occasionally	443	3.433(3.366,3.500)	3.438(3.370,3.505)	3.439(3.373,3.506)
	pd		0.001	P<0.01	0.034

a Model 1: Crude; b Model 2: Adjusted for sex, age; Additionally adjusted for BMI, only on child (yes or no), left-behind children(yes or no),father education (High school degree or below, Bachelor degree or above), mother education (High school degree or below, Bachelor degree or above), parent's marital status (first marriage, divorce, remarriage) TNF-α,IL-6 at baseline; c Model 3:sleep quality(good or bad), Depression level(continuous variables),physical activity(continuous variables),Internet Addiction (continuous variables) at baseline; d Adjusted data are expressed as odds ratio (95% confidence intervals).

Table 5 shows the relationships of Breakfast frequency with Inflammation level during the 3-year follow-up period. In Model 3,Inflammation level in the breakfast frequency was 4.882(4.421,4.692) for occasionally,4.638(4.566,4.709) for frequent,4.557(4.424,4.692)for Daily,(P for trend: P=0.01).

4. Discussion

Adolescence is a special life cycle that comprehensively promotes individual physical development and sexual maturity with the participation of multiple hormones. Due to the instability of the endocrine and energy metabolism systems, abnormal physical functions during adolescence can greatly increase the risk of developing metabolic syndrome in adulthood[12]Multiple epidemiological and observational studies have found a significant relationship between dietary habits, lifestyle factors, and the incidence of cardiovascular disease in adolescents. Chaotic dietary behavior is closely related to metabolic diseases such as obesity, dyslipidemia, and inflammation [13][14]Therefore, providing guidance on normal breakfast habits for teenagers has important value and role in promoting their physical and mental health development.

A prospective cohort study was conducted in Chinese middle school students to assess the relationship between breakfast frequency and the risk of cardiovascular disease. Multivariate logistic analyses showed that less breakfast frequency was significantly and independently related with higher risk of cardiovascular disease after adjusting for potential confounders. The results of this study are basically consistent with previous studies.[15][16][17]

Although the exact etiology of the association between breakfast frequency and risk of cardiovascular

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disease is not yet known, we explored several possible reasons. Regarding potential mechanisms underlying the relationship of the breakfast frequency with the risk of cardiovascular disease, a plausible explanation is that the association is mediated by Micronutrient. In addition, the impact of breakfast frequency on human energy metabolism is also an important triggering factor.

A study of U.S. military recruits by Fagnant [18] et al. found that breakfast skipping was strongly associated with vitamin D deficiency (VDD) in recruits, and a study of Brazilian adolescents found that high-frequency breakfast intake significantly improved adolescent vitamin D intake levels. Mielgo-Ayuso's survey of 1,058 European teenagers found that teens who skipped breakfast had significantly lower blood vitamin D and vitamin C concentrations than higher-frequency breakfast consumers [19]. Studies found that higher levels of vitamin D intake reduced plasma levels of inflammation and pain-related cytokines, such as PGE2, tumor necrosis factor alpha (TNF-α) and leukotrienes B4 (leukotriene B4, LTB4), prostaglandin E2 (Prostaglandin E2, PGE2)[20][21][22].In addition, studies targeting both adolescents and adults have shown that skipping breakfast is an important risk factor for insulin resistance [23] [24],When blood sugar control is impaired, it can cause an increase in neutrophil count, pro-inflammatory cytokine release, and oxidative stress response, exacerbating the body's inflammatory response [25].Queue studies have shown that skipping breakfast significantly enhances appetite and high energy intake, with adolescents who skip breakfast consuming more saturated fat. In addition, a sustained fasting state is more likely to increase insulin resistance, increase liver lipase activity, and stimulate the production of higher concentrations of HMG-CoA reductase, leading to higher concentrations of cholesterol[26][27].And high levels of blood lipids, blood sugar, and inflammation are also important triggers of hypertension[28][29].

5. Study strengths and limitations

This study has several advantages. This study is a prospective cohort study that can provide reliable sources of causal relationships. And this study considered and controlled for many confounding factors that may affect cardiovascular abnormalities. Therefore, the research results have certain guiding significance for the adolescent population who need to prevent cardiovascular diseases in clinical practice.

This study has some limitations. Firstly, the survey subjects of this study come from the same region, and the research results cannot represent the situation in other regions. Secondly, dietary habits and other data are self-reported. Therefore, it may be affected by recall bias. Finally, due to unknown or unmeasurable factors, the influence of confounding factors cannot be fully controlled.

6. Conclusion

This prospective cohort study indicates that a higher risk of cardiovascular disease was observed in populations with lower breakfast frequencies. Research suggests that teenagers should develop good dietary habits. Increase the frequency of breakfast consumption to prevent the occurrence of cardiovascular diseases.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

Author Zong Ji.Hao has given substantial contributions to the conception or the design of the manuscript, author Zong Ji.Hao to acquisition, analysis and interpretation of the data.

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