

BMJ Open Joint associations of fresh fruit intake and physical activity with glycaemic control among adult patients with diabetes: a cross-sectional study

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ABSTRACT

Objective To investigate the joint associations of fresh fruit intake and physical activity with glycaemic control in adult patients with diabetes mellitus (DM).

Design It was an observational study involving adult patients with DM through a face-to-face questionnaire survey, physical measurements and laboratory examinations. Data were analysed by introducing a generalised linear mixed model, and a significant difference was set at $p < 0.05$.

Setting Nanjing, Jiangsu, China.

Participants A total of 5663 adult patients with DM from the 2017 Nanjing Chronic Disease and Risk Factor Surveillance were recruited.

Results Based on the food frequency questionnaire, fresh fruit intake was classified as 'not eat', '1~99 g/day' and '≥100 g/day'. Physical activity level was calculated based on the data of Global Physical Activity Questionnaire and classified into insufficient physical activity (<600 MET-min/week) and sufficient physical activity (≥600 MET-min/week). The likelihood of glycaemic control in adult patients with DM with fresh fruit intake ≥100 g/day was 37.8% (OR: 1.378; 95% CI: 1.209 to 1.571) higher than those with fresh fruit intake <100 g/day, which was 26% (OR: 1.260; 95% CI: 1.124 to 1.412) higher in adult patients with DM with sufficient physical activity than those with insufficient physical activity. Adult patients with DM with fresh fruit intake ≥100 g/day and sufficient physical activity presented the greatest likelihood of glycaemic control (OR: 1.758; 95% CI: 1.471 to 2.102) compared with those with both fresh fruit intake <100 g/day and insufficient physical activity.

Conclusions Fresh fruit intake ≥100 g/day combined with sufficient physical activity is associated with a significantly higher likelihood of glycaemic control in adult patients with DM.

INTRODUCTION

Diabetes mellitus (DM) is one of the fastest growing health issues in the 21st century, the case number of which in adults has been tripled over the past 20 years. According to the latest report of the International Diabetes Federation (2019), the global prevalence of DM in adults is 9.3%, involving 463 million

Strengths and limitations of this study

- This study highlights the joint association of fresh fruit intake and physical activity with glycaemic control in adult patients with diabetes mellitus.
- This study analyses high-quality data from the population-based representative sample using a generalised linear mixed model, which avoids the clustering of data.
- This study does not assess glycaemic control using the representative indicator haemoglobin A1c.
- The cross-sectional study limits the assessment of causality.

affected adults.¹ DM is a significant risk of morbidity and premature mortality for blindness, cardiovascular, kidney and nerve diseases.²⁻⁴ Seriously, clinical management of DM and its complications has caused a heavy burden on public health and global economies.^{1,5}

An effective glycaemic control significantly decreases the risk of DM complications and prevents its aggravation.^{6,7} Current evidences have shown that multiple factors like the age, socioeconomic status, duration of disease, medication usage, comorbidities, body mass index (BMI), family history, behaviour and lifestyle are closely linked with glycaemic control.⁸⁻¹⁰ As an important component of daily diet, the intake of fruits is restricted in patients with DM because of the sugar content.¹¹ However, several studies have highlighted the role of fruit intake in controlling either haemoglobin A1c (HbA1c) or blood glucose.^{12,13} Furthermore, a physically active lifestyle has been reported to improve insulin sensitivity and glycaemic control in either healthy population, people with impaired glucose tolerance of patients with DM.¹⁴⁻¹⁶ Additionally, aerobic and resistance training have been validated as effective exercises

for controlling glycaemic in patients with type 2 DM (T2DM).¹⁷

Previous studies have suggested that keeping a combined low-risk lifestyle more effectively prevents the development of DM.^{18–19} We thereafter hypothesised that a proper intake of fresh fruits combined with sufficient physical activity may exert additional influences on glycaemic control compared with fresh fruit intake or physical activity alone. In the present study, we aim to investigate the joint association of fresh fruit intake and physical activity with glycaemic control in adult patients with DM.

Research design and methods

Study design and sampling

Data were collected from the 2017 Nanjing Chronic Disease and Risk Factor Surveillance (NCDRFS), which was a community-based cross-sectional study involving the regional representative population aged ≥ 18 years. In this survey, a stratified, multistage probability cluster sampling design was adopted. Briefly, five districts (Qinhuai, Xuanwu, Gulou, Qixia and Luhe) were selected for cluster sampling according to the permanent population, geographical region and economic development status in the first stage. In the second and third stage, four subdistricts and three neighbourhood communities were selected for probability proportional to size sampling, respectively. In the fourth stage, 50 households within each neighbourhood community were randomly sampled. In the fifth stage, one person with minimal 18 years was randomly selected from each household using the Kish selection grid. Finally, samples were stratified according to the sex and age distribution in China, on the basis of Chinese population data in 2006. Those who have lived in the current residence for at least 18 months were eligible to participate in this study, and at last, a total of 5663 adult patients with DM (type 1 or type 2) were recruited.

Data collection and measurement

At each surveillance point, trained staff were responsible for face-to-face collecting data according to a standard protocol at local community health service centres/stations of the participants' registration address, including questionnaire survey, physical measurements and laboratory examination results.

Physical measurements included the weight, height and blood pressure. Blood samples were collected from all subjects in the morning after an overnight fasting for at least 10 hours. Laboratory examinations included the fasting plasma glucose (FPG) and four items of blood lipids, which were performed within 8 hours of receiving the samples. FPG was measured enzymatically using a glucose oxidase method.

Variables

Dependent variables

DM was defined as FPG ≥ 7.0 mmol/L, or the use of hypoglycaemic agents, or any self-reported history of DM.²⁰ Glycaemic control was defined as FPG < 7.0 mmol/L according to the laboratory testing of this survey.

Independent variables

Fresh fruit intake was classified as 'not eat', '1~99 g/day' and ' ≥ 100 g/day' based on the semiquantitative Food Frequency Questionnaire (FFQ), which was used to assess dietary intake during the previous year. The reliability and validity of the FFQ have been previously reported.²¹ 'Not eat' and '1~99 g/day' were defined as fresh fruit intake < 100 g/day. Physical activity was assessed by the Global Physical Activity Questionnaire,²² which was categorised into occupational, leisure time, transportation, household work and sedentary activities (eg, watching television, using a computer, playing video games and reading during leisure time). The frequency and duration of each domain were recorded. Physical activity level was classified as ' < 600 MET-min/week' and ' ≥ 600 MET-min/week'. Insufficient physical activity was defined as physical activity < 600 MET-min/week.²³

Covariates

BMI was calculated using the formula: $BMI = \text{kg}/\text{m}^2$, where kg is a person's weight in kilograms and m^2 is the height in metres squared. $BMI = 18.5\text{--}23.9 \text{ kg}/\text{m}^2$, $< 18.5 \text{ kg}/\text{m}^2$, $\geq 24.0 \text{ kg}/\text{m}^2$ indicates the normal weight, low weight, overweight and obesity, respectively.²⁴ Current smoking was defined as smoking for 100 cigarettes in one's lifetime and currently smoking cigarettes. Current drinking was defined as alcohol intake for more than once per month during the past 12 months.²⁵ The education level was grouped based on the highest education level of primary school and lower, middle/high school and college and higher. Family history of DM was defined as the first-degree relatives with DM, including the father, mother, siblings and offspring.²⁶ Antidiabetic treatment depended on whether patients take antidiabetic medications regularly or irregularly.

The survey used to collect data in this study was presented in online supplemental table 1.

Quality control

A vigorous quality control was implemented by Nanjing Municipal Center for Disease Control and Prevention (Nanjing CDC) to ensure the reliability of data, which was conducted throughout the survey period, including design and revision of the preliminary plan, unifying investigation tools, preparation of standard training materials and technical requirements, field supervision, technical guidance and data analysis. A total of 10% of questionnaires were collected for verification and 5% of respondents were selected to review their physical measurements at each surveillance point. The feedback and correction were timely performed if there was any problem during quality control. All investigators were asked to participate in a uniform training programme and those passed the examination were qualified in this study. A manual of procedures was distributed by Nanjing CDC, and detailed instructions for administration of the questionnaires, anthropometric measurements and

biological specimen collection were provided. All data were cross-checked.

Statistical analysis

Participant characteristics were expressed as counts and percentages and they were stratified by fresh fruit intake and physical activity level. In order to avoid the clustering of data, a generalised linear mixed model (GLMM) was introduced for analysis. First, a two-level logistic regression model without explanatory variables was fitted, and the variance of level 2 was calculated to determine the high-level group aggregation effect. If it existed, a two-level logistic regression model with the participant and the corresponding community health service centre as the first and second level, respectively, was fitted. The adjusted model reported the results of GLMM after adjusting potential confounders (eg, sex, age, education level, smoking status, alcohol consumption, BMI, family history of DM and antidiabetic treatment) as previously reported.^{8–10} The multicollinearity in this model was tested. The relative risk was estimated by calculating the OR and corresponding 95% CI.

Data entry and management were performed using EpiData software, V.3.1. All statistical analyses were conducted using the SPSS system (V.20; IBM). A two-tailed p value <0.05 considered as statistically significant.

Patient and public involvement

No patients or public groups were involved in the conception, design and performance of this study.

RESULTS

A total of 5663 adult patients with DM completed the survey and examination. Classified by fresh fruit intake, there were 15.2%, 59.5% and 25.3% of cases as 'not eat', '1–99 g/day' and '≥100 g/day', respectively. Patients who did not take fresh fruit were more likely to maintain a normal weight compared with those with fresh fruit intake. Patients with fresh fruit intake ≥100 g/day were younger and more likely to have a family history of DM. Besides, patients with fresh fruit intake ≥100 g/day were more likely to achieve glycaemic control than those without fresh fruit intake or fresh fruit intake of 1–99 g/day and 54.9% of them maintained a physical activity level <600 MET-min/week. Insufficient physical activity was more likely to be reported in women, elderly over 60 years, those with lower education level, current smokers and those with poorer glycaemic control (table 1).

It is shown that the proportion of adult patients with DM achieving glycaemic control remained the lowest in those with fresh fruit intake <100 g/day and physical activity level <600 MET-min/week, which was the highest in those with both fresh fruit intake ≥100 g/day and physical activity level ≥600 MET-min/week (figure 1).

We further analysed the correlation between fresh fruit intake and glycaemic control in adult patients with DM. After adjusting the sex, age, education level, smoking

status, alcohol consumption, BMI, family history of DM and antidiabetic treatment, the greatest likelihood of glycaemic control was detected in patients with fresh fruit intake ≥100 g/day. Compared with those who did not take fresh fruit, patients with fresh fruit intake ≥100 g/day presented a higher odds of glycaemic control (OR: 1.512, 95% CI: 1.236 to 1.851). However, no significant difference in glycaemic control was detected between those without fresh fruit intake group and fresh fruit intake of 1–99 g/day (table 2). Based on this finding, adult patients with DM without fresh fruit intake and fresh fruit intake of 1–99 g/day were classified into one group as fresh fruit intake <100 g/day.

The correlation of fresh fruit intake (<100 g/day vs ≥100 g/day) or physical activity level (<600 MET-min/week vs ≥600 MET-min/week) with glycaemic control in adult patients with DM was respectively assessed. After adjusting the sex, age, education level, smoking status, alcohol consumption, BMI, family history of DM and antidiabetic treatment, the likelihood of glycaemic control was 37.8% lower in patients with fresh fruit intake <100 g/day than those with fresh fruit intake ≥100 g/day, which was 26% higher in patients with physical activity level ≥600 MET-min/week than those with <600 MET-min/week (table 3).

Subsequently, the joint association of fresh fruit intake and physical activity with glycaemic control was identified. Compared with those with fresh fruit intake <100 g/day and insufficient physical activity, odds of glycaemic control was higher in adult patients with DM with both fresh fruit intake ≥100 g/day and insufficient physical activity (OR: 1.468; 95% CI: 1.220 to 1.768), and those with both fresh fruit intake <100 g/day and sufficient physical activity (OR: 1.435; 95% CI: 1.256 to 1.639), while odds of glycaemic control was 75.8% higher in adult patients with DM with both fresh fruit intake ≥100 g/day and sufficient physical activity (OR: 1.758; 95% CI: 1.471 to 2.102) (table 4).

DISCUSSION

Through analysing the representative sample from 2017 NCD RFS, it is found that fresh fruit intake ≥100 g/day and sufficient physical activity alone or in combination significantly enhanced the likelihood of glycaemic control in adult patients with DM, suggesting that less fresh fruit intake combined with insufficient physical activity might be a high risk for poor glycaemic control.

Previous studies have reported multiple factors for glycaemic control in patients with DM, including the socioeconomic status, family history of DM, medication, obesity, dietary intake and physical activity.^{8–10} As an important component of daily diet, fruit is rich in fibre and bioactive substances.^{27–29} Nevertheless, fruit has been considered as an unfavourable factor for glycaemic control in patients with DM due to the high content of sugar.¹¹ Inconsistently, previous studies have shown that a sufficient intake of fresh fruit is able to reduce the risk

Table 1 Baseline characteristics of 5663 adult patients with DM classified by fresh fruit intake and physical activity level

Variable	n	Fresh fruit intake (g/day)			Physical activity (MET-min/week)	
		Not eat	1~99	≥100	<600	≥600
n (%)	5663 (100.0)	864 (15.2)	3368 (59.5)	1431 (25.3)	3110 (54.9)	2553 (45.1)
Gender (n, %)						
Male	3084 (54.5)	479 (55.4)	1847 (54.8)	758 (53.0)	1608 (51.7)	1476 (57.8)
Female	2579 (45.5)	385 (44.6)	1521 (45.2)	673 (47.0)	1502 (48.3)	1077 (42.2)
Age (years)						
18–49	1078 (19.0)	183 (21.2)	557 (16.5)	338 (23.6)	598 (19.2)	480 (18.8)
50–69	3334 (58.9)	469 (54.3)	2030 (60.3)	835 (58.4)	1745 (56.1)	1589 (62.2)
≥70	1251 (22.1)	212 (24.5)	781 (23.2)	258 (18.0)	767 (24.7)	484 (19.0)
Education level (n, %)						
Primary school and lower	1006 (17.8)	161 (18.6)	668 (19.8)	177 (12.4)	600 (19.3)	406 (15.9)
Middle/high school	3547 (62.6)	519 (60.1)	2095 (62.2)	933 (65.2)	1963 (63.1)	1584 (62.0)
College and higher	1110 (19.6)	184 (21.3)	605 (18.0)	321 (22.4)	547 (17.6)	563 (22.1)
Current smoking (n, %)						
No	4256 (75.2)	648 (75.0)	2511 (74.6)	1097 (76.7)	2395 (77.0)	1861 (72.9)
Yes	1407 (24.8)	216 (25.0)	857 (25.4)	334 (23.3)	715 (33.0)	692 (27.1)
Drinking (n, %)						
No	3998 (70.6)	627 (72.6)	2379 (70.6)	992 (69.3)	2292 (73.7)	1706 (66.8)
Yes	1665 (29.4)	237 (27.4)	989 (29.4)	439 (30.7)	818 (26.3)	847 (33.2)
Body mass index (kg/m ²)						
<18.5	91 (37.7)	37 (4.3)	29 (0.9)	25 (1.7)	52 (1.7)	39 (1.5)
18.5–23.9	2134 (1.6)	827 (95.7)	775 (23.0)	532 (37.2)	1150 (37.0)	984 (38.5)
≥24	3438 (60.7)	0 (0.0)	2564 (76.1)	874 (61.1)	1908 (61.4)	1530 (59.9)
Antidiabetic treatment (n, %)						
No	2372 (41.9)	346 (40.0)	1356 (40.3)	670 (46.8)	1360 (43.7)	1012 (39.6)
Yes	3291 (58.1)	518 (60.0)	2012 (59.7)	761 (53.2)	1750 (56.3)	1541 (60.4)
Familial history of DM (n, %)						
No	4205 (74.3)	654 (75.7)	2518 (74.8)	1033 (72.2)	2385 (76.7)	1820 (71.3)
Yes	1458 (25.7)	210 (24.3)	850 (25.2)	398 (27.8)	725 (23.3)	733 (28.7)
Glycaemic control (n, %)						
No	3410 (60.2)	514 (59.5)	2121 (62.6)	775 (55.0)	1949 (63.5)	1461 (56.3)
Yes	2253 (39.8)	350 (40.5)	1269 (37.4)	634 (45.0)	1118 (36.5)	1135 (43.7)

DM, diabetes mellitus.

of cardiovascular disease,^{30 31} some types of cancers³² and DM.^{33 34} Allan *et al*¹³ reported that there are no significant differences in glycaemic control, body weight and waist circumference between subjects with two pieces of fresh fruit per day and those with less fruit intake. In the present study, we consistently found that there was no significant difference in glycaemic control between adult patients with DM who did not eat fresh fruit and those with fresh fruit intake of 1~99 g/day. Moreover, adult patients with DM with fresh fruit intake ≥100 g/day presented 37.8% higher likelihood of glycaemic control than those with fresh fruit intake <100 g/day, which was

consistent with previous findings.^{35 36} Fresh fruit intake is favourable to glycaemic control due to the beneficial compounds like fibre, which contribute to enhance insulin sensitivity, delay the absorption of carbohydrates and inhibit the postprandial glucose load. In addition, abundant polyphenols in fruit fight against the oxidative stress that impairs the glucose uptake by cells.³⁴ Importantly, an effective glycaemic control is beneficial to decrease the risk of diabetic complications^{7 8} like carotid atherosclerosis,³⁷ diabetic vascular complications³⁸ and diabetic retinopathy.³⁹

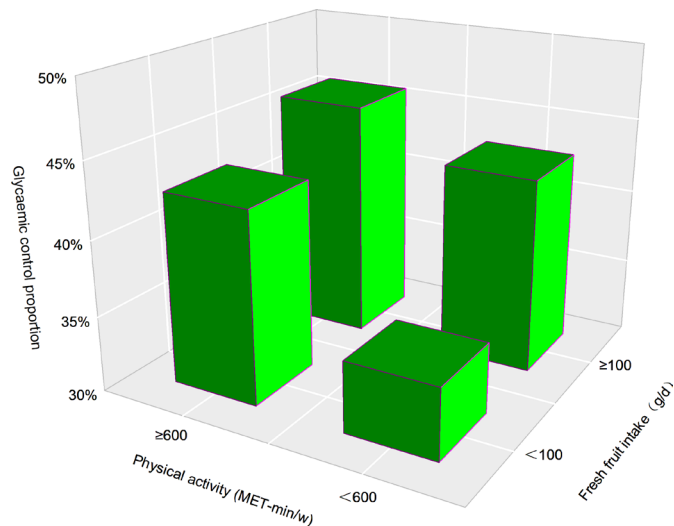


Figure 1 Joint association of fresh fruit intake and physical activity with the proportions of glycaemic control in adult patients with diabetes mellitus.

An adequate physical activity is good for enhancing insulin sensitivity, optimising BMI, and maintaining lipid metabolism, cardiorespiratory fitness and psychosocial well-being.¹⁶ A growing number of epidemiological studies have shown the correlation between physical activity and glycaemic control, the former of which is often recommended for patients with DM.^{14 16 17 20 40 41} Based on the data collected by the Global Physical Activity Questionnaire, our results revealed that the likelihood of glycaemic control was 26% higher in adult patients with DM with physical activity level ≥ 600 MET-min/week than those with < 600 MET-min/week. Although the exact mechanism underlying physical activity in glycaemic control has not been fully elucidated, many randomised controlled trials (RCTs) supported the role of exercise in effectively regulating the glycolipid metabolism disorder of patients with DM.⁴² Moreover, a regular exercise can significantly strengthen the ability of skeletal muscles to increase glucose uptake and transport via upregulating GLUT-4 protein in skeletal muscle cells.⁴³ A recent study emphasised that exercise intensity, volume and frequency are closely associated with the reduction of HbA1c, and physiological adaptations following a long-term regular exercise training contribute to maintain the effective glycaemic control and insulin sensitivity.¹⁷ Hordern *et al*⁴¹ suggested that the moderate-intensity aerobic physical

Table 2 OR (95% CI) of glycaemic control in 5663 adult patients with diabetes mellitus classified by fresh fruit intake

	OR	95% CI
Fresh fruit intake (g/day)		
Not eat	1.000	
~100	1.067	0.880 to 1.292
≥ 100	1.512	1.236 to 1.851

Table 3 OR (95% CI) of glycaemic control in 5663 adult patients with diabetes mellitus classified by fresh fruit intake and physical activity level

	OR	95% CI
Fresh fruit intake (g/day)		
< 100	1.000	
≥ 100	1.378	1.209 to 1.571
Physical activity (MET-min/week)		
< 600	1.000	
≥ 600	1.260	1.124 to 1.412

activity is conducive to maintain an ideal glycaemic control in patients with DM.

A growing number of studies have demonstrated that fresh fruit intake and physical activity significantly influence the primary, secondary and tertiary prevention of DM.^{17 33 36 41} Very latest, the combination of physical activity and healthy diet has been highlighted to enhance the likelihood of alleviating metabolic disorders.^{18 44} Theodora *et al*⁴⁴ considered that exercise alone is less effective than a combination of exercise and diet control on decreasing the incidence of DM. But for those who have already diagnosed as DM, the combined effect of fresh fruit intake and physical activity on glycaemic control has not been reported yet. Our study for the first time identified that sufficient fresh fruit intake and physical activity synergistically exerted the active effect on glycaemic control in adult patients with DM. Either fresh fruit intake ≥ 100 g/day (46.8%) or sufficient physical activity (43.5%) was independently correlated with the increased likelihood of glycaemic control in adult patients with DM, and notably, their combination resulted in a 75.8% higher likelihood of glycaemic control. Therefore, it is of great significance for adult patients with DM to maintain fresh fruits intake ≥ 100 g/day and at the same time, avoiding bad habits of insufficient physical activity, thus achieving an ideal glycaemic control.

In the present study, we highlighted the high-quality analysis of population-based representative data using the GLMM to avoid the clustering of data. However, some limitations should be noted. First of all, glycaemic

Table 4 Joint association of fresh fruit intake and physical activity with the likelihood of glycaemic control in adult patients with diabetes mellitus

	OR	95% CI
Fresh fruit intake < 100 g/day and insufficient physical activity	1.000	
Fresh fruit intake ≥ 100 g/day and insufficient physical activity	1.468	1.220 to 1.768
Fresh fruit intake < 100 g/day and sufficient physical activity	1.435	1.256 to 1.639
Fresh fruit intake ≥ 100 g/day and sufficient physical activity	1.758	1.471 to 2.102

control was assessed only by FPG, rather than the combination of HbA1c, and the duration of DM was not taken into consideration. Second, we fail to assess the volume and frequency of physical activity in adult patients with DM. Finally, our study was performed based on a cross-sectional study, and the causality should be further validated.

CONCLUSIONS

Fresh fruit intake ≥ 100 g/day combined with sufficient physical activity was significantly associated with the high likelihood of glycaemic control in adult patients with DM. Considering their synergistic effect, we recommended that sufficient fresh fruit intake combined with physical activity should be adopted as the self-management approach to maintain glycaemic control in adult patients with DM. Large-scale RCTs are still needed in the future to validate our findings, and it is also necessary to identify the potential influence of the volume and frequency of physical activity on glycaemic control in adult patients with DM.

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Competing interests None.

Patient consent for publication Not applicable.

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