British Journal of Nutrition (2021), 125, 926–933 doi:10.1017/S0007114520003438

Increased vegetable and fruit intake is associated with reduced failure rate of tuberculosis treatment: a hospital-based cohort study in China

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(Submitted 11 May 2020 – Final revision received 16 August 2020 – Accepted 18 August 2020 – First published online 2 September 2020)

Abstract

Increased intake of vegetables and fruits has been associated with reduced risk of tuberculosis infection. Vegetables and fruits exert immunoregulatory effects; however, it is not clear whether vegetables and fruits have an adjuvant treatement effect on tuberculosis. Between 2009 and 2013, a hospital-based cohort study was conducted in Linyi, Shandong Province, China. Treatment outcome was ascertained by sputum smear and chest computerised tomography, and dietary intake was assessed by a semi-quantitative FFQ. The dietary questionnaire was conducted at the end of month 2 of treatment initiation. Participants recalled their dietary intake of the previous 2 months. A total of 2309 patients were enrolled in this study. After 6 months of treatment, 2099 patients were successfully treated and 210 were uncured. In multivariate models, higher intake of total vegetables and fruits (OR 0·70; 95 % CI 0·49, 0·99), total vegetables (OR 0·68; 95 % CI 0·48, 0·97), dark-coloured vegetables (OR 0·61; 95 % CI 0·43, 0·86) and light-coloured vegetables (OR 0·67; 95 % CI 0·48, 0·95) were associated with reduced failure rate of tuberculosis treatment. No association was found between total fruit intake and reduced failure rate of tuberculosis treatment (OR 0·98; 95 % CI 0·70, 1·37). High intake of total vegetables and fruits, especially vegetables, is associated with lower risk of failure of tuberculosis treatment in pulmonary tuberculosis patients. The results provide important information for dietary guidelines during tuberculosis treatment.

Key words: Pulmonary tuberculosis: Vegetables: Fruit: Dietary assessment: Treatment outcome

Pulmonary tuberculosis is an infectious disease caused by *Mycobacterium tuberculosis*, and it is also a chronic wasting disease. *M. tuberculosis* bacilli are characterised by induction of chronic inflammation and intracellular survival[1]. In 2018, there were approximately 10 million new cases of tuberculosis and 1·24 million HIV-negative tuberculosis-associated deaths worldwide. China accounted for 9 % of the global tuberculosis incidence[2]. Although many countries have reduced their tuberculosis prevalence in the past few decades, the burdens are still high. Preventing and treating pulmonary tuberculosis remain to be crucial public health issues[3].

Epidemiological studies have indicated that malnutrition is associated with the occurrence and development of pulmonary tuberculosis[4,5] and can be a predictor for tuberculosis treatment failure[6]. The association between malnutrition and tuberculosis may be mediated by impaired immune function, increased oxidative stress, altered inflammation levels and dysfunctional gut microbiota[7–9]. During tuberculosis chemotherapy, excessive pro-inflammatory mediators can lead to T-cell signalling defects and immune effector dysfunction, and this hyper-inflammatory reaction may continue through treatment completion, thereby adversely affecting treatment outcome[10–13]. Additionally, foods rich in fibre promote SCFA production and can control the intestinal immune response by increasing transforming growth factor-β, reducing proinflammatory cytokines[14,15]. Several studies have indicated that micronutrient deficiencies are relatively common in tuberculosis patients and that they can delay sputum smear conversion, exacerbate tuberculosis symptoms and affect tuberculosis treatment[16–18]. Vegetables and fruits are important components of a balanced diet, and they are as a source of vitamins, especially vitamins C and E, minerals, fibre and phytochemicals[19]. Vegetables and fruits exert anti-inflammatory effects, play a role in immunoregulation[20,21] and may be beneficial for treating pulmonary tuberculosis.

However, several observational studies have indicated that inadequate intake of vegetables and fruits is associated with

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increased risk of tuberculosis infection[22–24]. To the authors' knowledge, limited research has been conducted on the dietary effect on tuberculosis treatment outcome. Consequently, the purpose of this study was to investigate the effect of vegetable and fruit intake on tuberculosis treatment outcome.

Methods

Ethics

The study was approved by the Medical Ethic Committee of Qingdao Municipal Center for Disease Control and Prevention, and all aspects of this study complied with the Declaration of Helsinki. This study was registered as ChiCTR-OCC-10000994 in the Chinese Clinical Trial Registry.

Study design and population

Between 2009 and 2013, a hospital-based cohort study was conducted in Linyi, Shandong Province, China. Seven hospitals or tuberculosis clinics were randomly selected for the study including Lanshan, Yishui, Tancheng, Yinan, Cangshan, Feixian and Pingyi. Each site had a defined catchment area including approximately 0·9 million residents. The three-tier health care delivery system constituted the existing health care system, and the tuberculosis control programme was centralised. The basic units of the tuberculosis health care system were the hospitals or tuberculosis clinics which were responsible for tuberculosis diagnosis, treatment and patient management guided by the national tuberculosis control programme[25]. This was a *post hoc* analysis. In this study, study staff screened 2716 potential participants. A total of 407 participants were excluded due to (1) declining to participate (*n* 97); (2) meeting exclusion criteria (*n* 212) or (3) having incomplete data or implausible values from the diet history questionnaires (*n* 98). The final analytic population to evaluate associations with diet included 2309 participants. The flow chart of the study population is shown in Fig. 1.

The inclusion criteria were (1) being 18 years of age or older and (2) diagnosed as having pulmonary tuberculosis. Patients with clinical and radiographic abnormalities consistent with pulmonary tuberculosis and those suspected to have pulmonary tuberculosis were examined by sputum smear. If the sputum smear was positive, the patient was diagnosed with smear-positive pulmonary tuberculosis; if the sputum specimen was negative and the computerised tomography scan of the chest was compatible with active pulmonary tuberculosis, the patient was diagnosed with smear-negative pulmonary tuberculosis after discussion of the radiographic and clinical doctors[26]. The final inclusion criterion was (3) providing informed consent. The exclusion criteria were (1) clinical evidence of extrapulmonary tuberculosis, drug-resistant tuberculosis, organ dysfunction or neoplasm or being HIV positive; (2) having diseases that impaired eating; (3) having cognitive dysfunction or mental disorder and (4) being pregnant or lactating.

Ascertainment of regimens and treatment outcome

Patients diagnosed with pulmonary tuberculosis were followed up prospectively until completion of the standard 6-month tuberculosis treatment. Tuberculosis treatments used in this study were in line with the China Tuberculosis Control Collaboration strategy[27]. To be specific, the standard regimen was used which consisted of four drugs (e.g. isoniazid, rifampicin, ethambutol and pyrazinamide) during the initial 2 months followed by isoniazid and rifampicin for the next 4 months[26]. During the first month of hospitalisation, participants purchased meals by themselves according to their normal dietary habits. Subsequently, the patients were discharged from the hospital for home treatment and periodic re-examination.

The National Tuberculosis Control Programme Guidelines in China[26] were based on the definitions and reporting framework for tuberculosis organised by the WHO[28]. Treatment success was defined as patients who were cured and those who completed treatment. The criteria patients with successful treatment were received all treatments, had two consecutive negative sputum smear results, one of which was obtained at the end of the treatment and had no active lesions detected by computerised tomography scan. The treatment outcomes were obtained from the patients' medical records.

Dietary assessment

Dietary intake was assessed with a semi-quantitative FFQ. The questionnaire was formulated based on the foods with higher intake frequency according to the 2002 national nutrition survey in China that was developed and previously locally validated[29,30]. All the participants were surveyed face to face by trained medical staff and project investigators to ensure good compliance of the respondents and quality of the questionnaire. The dietary questionnaire was conducted at the end of month two of treatment initiation. Participants recalled their dietary intake of the previous 2 months. The frequency options for vegetables and fruits included 'three times a day', 'twice a day', 'once a day', 'four to five times a week', 'two to three times a week', 'once a week', 'once every 2 weeks', 'once a month', 'once every 2 months' and 'almost never'. A standard portion size was specified for vegetables and fruits, and participants were asked to denote their usual portion size from several options (<0·5 times, standard, >1·5 times or other). Vegetable and fruit intake was calculated by multiplying the portion size of a single serving of each food by its reported frequency of intake and then dividing by the time corresponding to the frequency of intake. Tools for data collection were a structured questionnaire, medical records, food-model booklets and locally available bowls, plates and cups for measuring or estimating the amount of food consumed.

In the study, total vegetables were divided into dark-coloured vegetables and light-coloured vegetables[31]. Dark-coloured vegetables refer to those that are dark green, red, orange and purple. Light-coloured vegetables refer to those that are white, yellowish and slightly green. In view of the residents' dietary habits in Linyi city, the researchers selected fifteen specific types of vegetables for qualitative research. Then participants were asked to recall whether they often ate one of the fifteen specific types of vegetables; if they responded 'several times a month or a week', the status of regular consumption was assessed. On the contrary, participants responded 'never or infrequently' if they

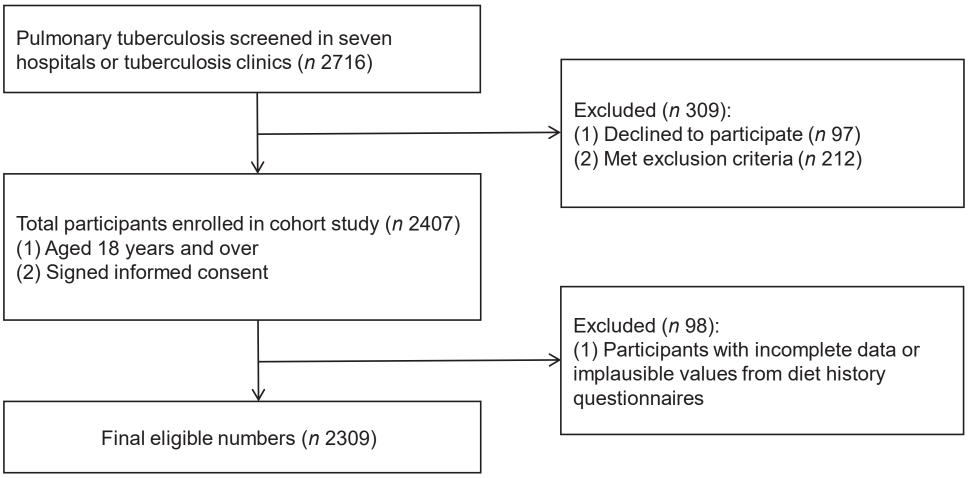

Fig. 1. Flow chart of the study population.

seldom ate the vegetable, and the status of little consumption was assessed.

Covariates

Information was collected on age, sex, height and weight. BMI (kg/m^2) was calculated as body weight in kg divided by the square of height in m. The physique was classified as underweight, normal weight, overweight or obese according to the BMI values for the Chinese population (<18·5, 18·5–23·9 and ≥24 kg/m^2)[32]. Other information collected included education completed (none, primary school, class VII–IX, class X–XII, diploma or higher), occupation (unskilled farmer or worker, student, professional, retired or other), marital status (single, divorced, widowed or married), lifestyle parameters including history of smoking, drinking and regular exercise, geographic location (Lanshan, Yishui, Tancheng, Yinan, Cangshan, Feixian or Pingyi), season of FFQ return (winter (December–February), spring (March–May), summer (June–August), autumn (September–November)) and total energy intake (kcal/d).

Statistical analysis

The survey data were analysed with SPSS version 19.0. In this study, qualitative data are expressed as numbers and percentages. Quantitative data are described as medians and interquartile ranges because of their non-normal distributions based on the Kolmogorov–Smirnov normality test. The statistical difference for the characteristics between the treatment success and the treatment failure groups was assessed with a χ^2 test for categorical variables and a Mann–Whitney *U* test for non-normal continuous variables. The intake of vegetables and fruits was categorised with tertiles according to their distributions in the study population. The associations between total vegetables and fruits, total vegetables, total fruits, dark-coloured vegetables, light-coloured vegetables, specific types of vegetables (regular consumption *v.* little consumption) and the failure rate of tuberculosis treatment were appraised by binary logistic regression. The lowest tertile of intake or little consumption was used as the reference category. Through univariate analysis, we determined the variables (BMI, marital status) related to treatment outcome. Additionally, variables previously reported to be associated with outcome (age[33], sex[33], education completed[34], occupation[35], smoking[36], drinking[36], regular exercise[37] and total energy intake[38]) were considered potential confounders. The crude model was unadjusted; model 1 was adjusted for age and sex; model 2 was adjusted for age, sex, BMI, education completed, occupation, marital status, smoking, drinking, regular exercise and total energy intake. Furthermore, stratified analyses were performed based on sex and smoking status to evaluate the relationship between total vegetable and fruit intake and the risk of failure of tuberculosis treatment.

The Box–Tidwell procedure was utilised to test the linearity between the continuous independent variables and the dependent variables[39]. The interactions of the continuous independent variables and their natural logarithm conversion values were incorporated into the regression model. To protect against type I error, Bonferroni's correction was used. The tolerance and variance expansion factor was used to test the collinearity among the independent variables. Tolerance <0·1 or variance expansion factor > 10 meant that collinearity existed. The linear trend for the vegetable and fruit variables was tested by using the median values of each category and including them as continuous variables in the logistic regression model. Adjusted OR and 95 % CI were reported to indicate the strength and direction of associations. For all analyses, $P < 0·05$ or $P < 0·01$ was considered statistically significant (* $P < 0·05$, ** $P < 0·01$). All P values were two sided. The data were verified after collection, and confidentiality was maintained.

Results

The characteristics of the 2309 participants are shown in Table 1. After 6 months of treatment, 2099 patients were successfully treated and 210 were uncured. The success rate was 90·91 %. No significant difference was detected between the successful treatment and failed treatment groups for age, sex, education completed, marital status, occupation, smoking, drinking, regular exercise, geographic location, season of FFQ return or total energy intake. However, the

British Journal of Nutrition

https://doi.org/10.1017/S0007114520003438 Published online by Cambridge University Press

British Journal of Nutrition

Table 1. Baseline characteristics of study subjects (*n* 2309)*
(Numbers and percentages; median values and interquartile ranges (IQR))

	Treatment outcome				
	Successful		Failed		
	n	%	*n*	%	*P*
Number of subjects	2099	90·91	210	9·09	
Sex					
Male	1635	77·89	151	71·90	0·14
Female	464	22·11	59	28·10	
Age (years)					
Median	54		56		0·09
IQR	36–65		39–69		
Education completed					
None	531	25·30	62	29·52	0·27
Primary school	666	31·73	62	29·52	
Class VII–IX	657	31·30	64	30·48	
Class X–XII	189	9·00	13	6·19	
Diploma or higher	56	2·67	9	4·29	
Marital status					
Single	310	14·77	29	13·81	0·01
Married	1678	79·94	164	78·10	
Widowed	107	5·10	14	6·67	
Divorced	4	0·19	3	1·42	
Occupation					
Unskilled farmer or worker	1996	95·09	204	97·14	0·25
Student	17	0·81	1	0·48	
Professional	32	1·52	4	1·90	
Retired	7	0·34	1	0·48	
Other	47	2·24	0	0	
BMI					
<18·5 kg/m^2	396	18·87	41	19·52	0·02
18·5 to <23·9 kg/m^2	1497	71·32	136	64·76	
≥24 kg/m^2	206	9·81	33	15·72	
Smoking					
No	1515	72·18	156	74·29	0·52
Yes	584	27·82	54	25·71	
Drinking					
No	1756	83·66	182	86·67	0·26
Yes	343	16·34	28	13·33	
Regular exercise					
No	953	45·40	107	50·95	0·12
Yes	1146	54·60	103	49·05	
Geographic location					
Lanshan	307	14·63	26	12·38	0·64
Yishui	540	25·73	50	23·81	
Tancheng	348	16·58	32	15·24	
Yinan	205	9·77	22	10·48	
Cangshan	290	13·81	30	14·29	
Feixian	111	5·29	17	8·09	
Pingyi	298	14·19	33	15·71	
Season of FFQ return					
Winter (December–February)	473	22·53	49	23·33	0·74
Spring (March–May)	536	25·54	48	22·86	
Summer (June–August)	502	23·92	48	22·86	
Autumn (September–November)	588	28·01	65	30·95	
Total energy intake (kcal/d)†					
Median	1686		1686		0·13
IQR	1362–1879		1534–1737		

* Categorical variables are presented as *n* and % while non-normal continuous variables are presented as medians and IQR. *P* values derived from χ^2 tests for categorical variables and Mann–Whitney *U* tests for non-normal continuous variables.
† To convert kcal to kJ, multiply by 4·184.

successful treatment and failed treatment groups showed significant differences in BMI ($P = 0·02$) and marital status ($P = 0·01$).

As shown in Table 2, compared with the failed treatment group, the successful treatment group showed higher intake of total vegetables and fruits (200·00 *v.* 175·00 g/d, $P = 0·007$), total vegetables (142·86 *v.* 109·59 g/d, $P = 0·004$), dark-coloured vegetables (64·29 *v.* 42·86 g/d, $P < 0·001$) and light-coloured vegetables (85·71 *v.* 64·29 g/d, $P = 0·02$).

The OR of treatment outcome according to tertiles of total vegetables and fruits, total vegetables, dark-coloured vegetables,

https://doi.org/10.1017/S0007114520003438 Published online by Cambridge University Press

Table 2. Comparison with daily vegetable and fruit intake between the successful treatment and failed treatment groups*
(Median values and interquartile ranges (IQR))

	Treatment outcome				
	Successful (*n* 2099)		Failed (*n* 210)		
	Median	IQR	Median	IQR	*P*
Total vegetables and fruits (g/d)	200·00	114·29–300·00	175·00	95·54–257·14	0·007
Total vegetables (g/d)	142·86	71·43–200·00	109·59	57·14–200·00	0·004
Dark-coloured vegetables (g/d)	64·29	28·57–100·00	42·86	24·11–100·00	<0·001
Light-coloured vegetables (g/d)	85·71	36·99–100·00	64·29	28·57–100·00	0·02
Total fruits (g/d)	28·57	0–64·29	28·57	3·01–71·42	0·59

* Non-normal continuous variables are presented as medians and IQR. *P* values derived from Mann–Whitney *U* tests for non-normal continuous variables.

light-coloured vegetables and total fruits are shown in Table 3. Compared with the lowest tertile, total vegetable and fruit intake for the highest tertile was inversely associated with the risk of failure of tuberculosis treatment; the OR was 0·70 (95 % CI 0·49, 0·99) in multivariate model 2. The intake of total vegetables was significantly associated with reduced risk of failure of tuberculosis treatment in the multivariate analysis (OR 0·68, 95 % CI 0·48, 0·97). Moreover, when we examined the association between vegetables according to colour categories and tuberculosis treatment outcome after adjustment for multiple confounders, compared with the lowest tertile, the OR of tuberculosis treatment outcome for the highest tertile intakes of dark-coloured vegetables and light-coloured vegetables were 0·61 (95 % CI 0·43, 0·86) and 0·67 (95 % CI 0·48, 0·95), respectively. No association was found between total fruit intake and reduced failure rate of tuberculosis treatment (OR 0·98, 95 % CI 0·70, 1·37).

The association between total vegetable and fruit intake and the failure rate of tuberculosis treatment in stratified analyses are shown in Table 4. In stratified analyses by sex, compared with the lowest tertile, total vegetable and fruit intake in males for the highest tertile was inversely associated with the risk of failure of tuberculosis treatment with an OR of 0·65 (95 % CI 0·43, 0·98) in model 2. In stratified analyses by smoking, no association was found between total vegetable and fruit intake and reduced failure rate of tuberculosis treatment.

The OR of treatment outcome according to regular or little consumption of specific types of vegetables are shown in Table 5. After adjustment (model 2), the OR of tuberculosis treatment outcome for eating Chinese cabbage, spinach, radish, oilseed rape, eggplant, carob, tomato, cucumber, cauliflower and scallion were 0·52 (95 % CI 0·38, 0·71), 0·52 (95 % CI 0·39, 0·70), 0·65 (95 % CI 0·46, 0·92), 0·70 (95 % CI 0·50, 0·96), 0·55 (95 % CI 0·40, 0·76), 0·65 (95 % CI 0·48, 0·87), 0·53 (95 % CI 0·39, 0·71), 0·49 (95 % CI 0·36, 0·66), 0·61 (95 % CI 0·39, 0·94) and 0·56 (95 % CI 0·41, 0·76), respectively.

Discussion

In the present study, we found that sufficient intake of total vegetables and fruits, total vegetables, dark-coloured vegetables and light-coloured vegetables is associated with lower risk of failure of tuberculosis treatment. Regular consumption of Chinese cabbage, spinach, radish, oilseed rape, eggplant, carob, tomato, cucumber, cauliflower and scallion is inversely associated with the risk of failure of tuberculosis treatment.

Several previous studies have indicated a protective effect of vegetable and fruit intake on tuberculosis infection[22–24]. Sarita Aguirre found individuals with limited vegetables in their diet had an increased risk of respiratory symptoms related to tuberculosis[40]. He *et al.*[41] found that vitamin C, vitamin E and superoxide dismutase in fresh vegetables and fruits constitute an antioxidant network during dietary intervention for patients with pulmonary tuberculosis complicated with type 2 diabetes, contributing to reducing malondialdehyde content, scavenging free radicals and reducing the proportion of patients with sputum positive for bacilli. These studies provided epidemiological evidence between vegetable and fruit intake and tuberculosis, supporting our findings to a certain extent. *M. tuberculosis* induces reactive oxygen species and reactive nitrogen species, and the equilibrium of pulmonary function between oxidant and antioxidant status is disturbed, thus provoking an inflammatory state and giving rise to immune suppression[42]. Vegetables and fruits may maintain this balance through anti-inflammatory and antioxidant effects, thus having beneficial effects on tuberculosis treatment. Nonetheless, the association between total fruit intake and reduced failure rate of tuberculosis treatment was not statistically significant. This may have been due to low intake of fruits by local people. Household income, fruit prices and regional dietary habits may be important constraints. Thus, the results indicate possible evidence for a relationship between fruit intake and treatment outcome that warrants further investigation.

Importantly, a large body of epidemiological evidence suggests that certain types of vegetables, particularly cruciferous vegetables (e.g. cauliflower, radish), dark-green leafy vegetables (e.g. celery[43], oilseed rape, spinach[44], swamp cabbage) have substantial health-promoting activities. Although not yet completely understood, phytochemicals and antioxidants within these vegetables can have multiple effects including decreasing activity of pro-inflammatory cytokines, reducing oxidative damage and even stimulating the immune system[14,21]. Overall, most cell and animal studies supported a potential role for certain types of vegetables and their ingredients in tuberculosis prevention and treatment.

Several advantages of this study should be mentioned. First, to the authors' knowledge, this was the first study to explore the

Table 3. Association of vegetable and fruit intake with the failure rate of tuberculosis treatment
(Odds ratios and 95 % confidence intervals)

		Crude model†		Model 1‡		Model 2§	
	Successful/failed (*n*/*n*)	OR	95 % CI	OR	95 % CI	OR	95 % CI
Total vegetables and fruits (g/d)							
<135·71	682/86	Reference		Reference		Reference	
135·71 to <242·86	649/59	0·72	0·51, 1·02	0·71	0·50, 1·01	0·74	0·51, 1·05
≥242·86	768/65	0·67*	0·48, 0·94	0·69*	0·49, 0·97	0·70*	0·49, 0·99
P_{trend}‖		0·02		0·03		0·04	
Total vegetables (g/d)							
<85·71	700/83	Reference		Reference		Reference	
84·71 to <200·00	520/57	0·90	0·62, 1·30	0·89	0·62, 1·28	0·91	0·63, 1·33
≥200·00	879/70	0·65*	0·46, 0·92	0·66*	0·47, 0·94	0·68*	0·48, 0·97
P_{trend}‖		0·01		0·02		0·02	
Dark-coloured vegetables (g/d)							
<42·86	669/88	Reference		Reference		Reference	
42·86 to <100·00	551/54	0·75	0·52, 1·07	0·74	0·52, 1·06	0·77	0·53, 1·11
≥100·00	879/68	0·59**	0·42, 0·82	0·60**	0·43, 0·84	0·61**	0·43, 0·86
P_{trend}‖		0·002		0·003		0·003	
Light-coloured vegetables (g/d)							
<42·86	536/70	Reference		Reference		Reference	
42·86 to <100·00	600/57	0·73	0·50, 1·05	0·72	0·50, 1·04	0·73	0·50, 1·05
≥100·00	963/83	0·66*	0·47, 0·92	0·67*	0·48, 0·93	0·67*	0·48, 0·95
P_{trend}‖		0·02		0·02		0·02	
Total fruits (g/d)							
<14·29	661/69	Reference		Reference		Reference	
14·29 to <42·86	505/46	0·87	0·59, 1·29	0·88	0·59, 1·30	0·84	0·56, 1·25
≥42·86	933/95	0·98	0·70, 1·35	0·98	0·71, 1·36	0·98	0·70, 1·37
P_{trend}‖		0·93		0·95		0·96	

* $P < 0·05$, ** $P < 0·01$.
† Crude model unadjusted.
‡ Model 1 adjusted for age and sex.
§ Model 2 adjusted for age, sex, smoking, drinking, BMI, education completed, marital status, occupation, regular exercise and total energy intake.
‖ Tests for linear trend were carried out by logistic regression, using a median value of each exposure intake category as a single.

Table 4. Association of total vegetable and fruit intake with the failure rate of tuberculosis treatment, stratified by sex and smoking status
(Odds ratios and 95 % confidence intervals)

		Crude model†		Model 2‡	
Total vegetables and fruits (g/d)	Successful/failed (*n*/*n*)	OR	95 % CI	OR	95 % CI
Male					
<135·71	532/66	Reference		Reference	
135·71 to <242·86	490/39	0·64	0·42, 0·97	0·67	0·44, 1·02
≥242·86	613/46	0·61*	0·41, 0·90	0·65*	0·43, 0·98
Female					
<135·71	150/20	Reference		Reference	
135·71 to <242·86	159/20	0·94	0·49, 1·82	0·77	0·38, 1·58
≥242·86	155/19	0·92	0·47, 1·79	0·82	0·40, 1·69
Smoking status – yes					
<135·71	220/28	Reference		Reference	
135·71 to <242·86	201/15	0·59	0·30, 1·13	0·58	0·29, 1·16
≥242·86	163/11	0·53	0·26, 1·10	0·50	0·23, 1·07
Smoking status – no					
<135·71	462/58	Reference		Reference	
135·71 to <242·86	448/44	0·78	0·52, 1·18	0·80	0·52, 1·21
≥242·86	605/54	0·71	0·48, 1·05	0·75	0·50, 1·13

* $P < 0·05$, ** $P < 0·01$.
† Crude model unadjusted.
‡ Model 2 adjusted for age, sex, smoking, drinking, BMI, education completed, marital status, occupation, regular exercise and total energy intake. The corresponding stratified variables were excluded from the adjusted model.

association of vegetable and fruit intake on the outcome of tuberculosis treatment. Second, this study subdivided vegetables into dark-coloured vegetables and light-coloured vegetables, which greatly enhanced the practicality, and the colour categories were beneficial for menu planning[45]. Third, certain kinds of vegetables may affect tuberculosis treatment. Therefore, this was the first study to qualitatively investigate the relationship between specific types of vegetables and reduced failure rate of tuberculosis treatment. Awareness of the intake, colour category and specific types of vegetables provides context into how people with tuberculosis select food and may enhance intervention strategies aimed at improving dietary practice to promote health

Table 5. Association of specific types of vegetables consumption with the failure rate of tuberculosis treatment (Odds ratios and 95 % confidence intervals)

	Crude model†§			Model 2‡§		
Food items	OR	95 % CI	*P*	OR	95 % CI	*P*
Chinese cabbage	0·50	0·38, 0·68	<0·001	0·52	0·38, 0·71	<0·001
Celery	0·84	0·62, 1·15	0·29	0·87	0·63, 1·20	0·39
Spinach	0·52	0·39, 0·69	<0·001	0·52	0·39, 0·70	<0·001
Radish	0·63	0·45, 0·88	0·006	0·65	0·46, 0·92	0·01
Oilseed rape	0·67	0·49, 0·92	0·01	0·70	0·50, 0·96	0·03
Eggplant	0·55	0·41, 0·75	<0·001	0·55	0·40, 0·76	<0·001
Carob	0·64	0·48, 0·85	0·002	0·65	0·48, 0·87	0·004
Kidney bean	0·84	0·59, 1·19	0·32	0·84	0·58, 1·21	0·34
Tomato	0·52	0·38, 0·69	<0·001	0·53	0·39, 0·71	<0·001
Cucumber	0·49	0·37, 0·66	<0·001	0·49	0·36, 0·66	<0·001
Swamp cabbage	0·50	0·17, 1·46	0·20	0·46	0·15, 1·41	0·17
Cauliflower	0·57	0·38, 0·87	0·009	0·61	0·39, 0·94	0·02
Lentil bean	0·64	0·27, 1·54	0·32	0·62	0·25, 1·52	0·30
Scallion	0·55	0·41, 0·73	<0·001	0·56	0·41, 0·76	<0·001
Loofah	0·48	0·21, 1·09	0·08	0·45	0·19, 1·06	0·07

* $P < 0·05$, ** $P < 0·01$.
† Crude model unadjusted.
‡ Model 2 adjusted for age, sex, smoking, drinking, BMI, education completed, marital status, occupation, regular exercise and total energy intake.
§ The little consumption group was used as the reference group.

in this growing portion of the population living with a chronic wasting disease.

Nevertheless, some limitations of this study need to be acknowledged. First, there was a potential risk of recall bias regarding dietary intake, as this information relied on the participants' ability to recall their dietary intake[46]. Moreover, dietary information was not measured repeatedly, and measurement error in the FFQ might occur if the participants changed their diet over time. In this study, however, it was expected that dietary patterns among adults were relatively stable over time, based on other longitudinal studies that showed minimal temporal changes[47,48]. Second, although many potential confounders were controlled, household income and other socio-economic factors[49,50] were not considered and could have affected the results. Third, different cooking methods and storage methods can lead to different nutritional values of vegetables and fruits. The information was not accounted in this study.

Conclusion

In conclusion, high intake of total vegetables and fruits, especially vegetables, is associated with lower risk of failure of tuberculosis treatment in pulmonary tuberculosis patients. The results provide important information for dietary guidelines during tuberculosis treatment.

Acknowledgements

The authors would like to thank the medical staff of Linyi People's Hospital East Branch and county hospitals or tuberculosis clinics for their support.

The study was supported by the National Natural Science Foundation of China (grant no. 81872610 to Aiguo Ma).

The authors' contributions were as follows: conceptualisation: A. M. and S. Z.; data curation: J. C.; investigation: Q. W. and J. C.; formal analysis: L. X. and J. Z.; funding acquisition: A. M.; methodology: A. M.; project administration: S. Z.; resources: S. Z. and A. M.; supervision: Y. M.; validation: J. W. and S. L.; writing - original draft: L. X.; writing - review and editing: J. W., K. X. and A. M.. All authors approved the final manuscript.

The authors declared no conflicts of interest.

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British Journal of Nutrition