

Height, age at menarche, body weight and body mass index in life-long vegetarians

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Abstract

Objective: We investigated whether life-long adherence to a vegetarian diet is associated with adult height, age at menarche, adult body weight and body mass index (BMI), used as indicators of growth, development and obesity, in a large sample of adults.

Design: This was a cross-sectional study. Anthropometric data and information on age, ethnicity, education, age at menarche and age at becoming a vegetarian were obtained through a questionnaire. Self-reported height and weight were calibrated using predictive equations derived from a previous validation study.

Setting: United Kingdom.

Subjects: The study includes 45 962 British men and women aged ≥ 20 years of whom 16 083 were vegetarians (not eating fish or meat).

Results: In men and women, there were no significant differences in height, weight or BMI between life-long vegetarians ($n = 125$ (men) and $n = 265$ (women)) and people who became vegetarian at age ≥ 20 years ($n = 3122$ (men) and $n = 8137$ (women)). Nor was there a significant difference in age at menarche between life-long vegetarian women and women who became vegetarian at age ≥ 20 years.

Conclusion: This study suggests that, compared with people who become vegetarian when adult, life-long vegetarians do not differ in adult height, weight, BMI or age at menarche in women.

Keywords
Vegetarians
Growth
Development

The majority of the world population consumes a largely plant-based diet. In developing countries, restricted diets may result from a limited availability of foods, whereas in developed countries people may choose a meat-free diet for various reasons. The number of vegetarians in Western countries is difficult to estimate. According to a 2001 poll, the proportion of vegetarians in the adult British population was estimated to be 4%, i.e. around 2 million people, a figure that has doubled since the beginning of the 1980s. The figure rose to 7 million when those who reported that they avoid eating red meat were included¹. Data from the USA suggest that 2.8% of the adult population, i.e. 5.7 million American adults, are vegetarians².

A well-planned vegetarian diet is considered to be nutritionally adequate for all stages of the life cycle, including infancy, childhood and adolescence³. However, epidemiological data on growth and development in long-term vegetarians are still sparse. Most previous studies have been relatively small and mainly concerned infants or pre-school-aged children. Larger studies on California Seventh-Day Adventists have shown that vegetarian children and adolescents grow at least as rapidly as

non-vegetarians^{4,5}; however, indications of delayed physical maturation in vegetarian girls have been observed⁶.

The Oxford arm of the European Prospective Investigation into Cancer and Nutrition (EPIC–Oxford) was designed to recruit a large number of vegetarians in the UK. In a sample of 45 962 subjects of whom 16 083 were vegetarians, we compared height, age at menarche, body weight and body mass index (BMI) between life-long vegetarians and subjects who became vegetarian later in life.

Methods

Subjects

The participants in this study were selected from the EPIC–Oxford cohort, which consists of 65 500 participants aged ≥ 20 years and living in the UK between 1993 and 1999⁷. The aim was to recruit participants with a wide range of diets by targeting vegetarians and vegans as well as the general UK population. Participants were recruited through collaborating general practitioners or by post via vegetarian and vegan societies, vegetarian and health food

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magazines, or were friends or relatives of other participants. They completed a detailed questionnaire including questions on age, diet, anthropometric measures, ethnicity, education and age at menarche. The study protocol received approval by a multi-centre research ethics committee. The current study is based on the subjects recruited by post; in these subjects the anthropometric data were self-reported. The analysis was restricted to subjects of known ethnicity, age left school and age at becoming vegetarian, leaving 45 962 subjects in the study of whom 16 083 were vegetarians. For the analysis of each of height, age at menarche, body weight and body mass index (BMI), exclusions were also made if data were missing or considered unreliable (for men: height <100 or >213 cm, weight <30 kg, BMI <15 or >60 kg m⁻²; for women: height <100 or >198 cm, weight <20 kg, BMI <15 or >60 kg m⁻²; age at menarche <8 years). The numbers of subjects with data for each variable are given in Table 1.

Classification of study groups

Classifications of vegetarian status and age at becoming vegetarian were based on four questions: 'Do you eat any meat (including bacon, ham, poultry, game, meat pies, sausages)? (Yes/No). If no, how old were you when you last ate meat?' and 'Do you eat any fish? (Yes/No). If no, how old were you when you last ate fish?' Subjects who

reported that they ate meat and/or fish were classified as non-vegetarians and subjects who reported that they did not eat meat or fish were classified as vegetarians. Age at becoming vegetarian was defined as the age at which they last ate meat or fish. Two additional questions related to the intakes of milk and eggs, which enabled us to identify vegans (who exclude all animal products). However, because of their small number, 695 men and 1188 women (of whom two were life-long vegans), the vegans were not analysed separately. On the basis of their vegetarian status and age at becoming vegetarian, the subjects were divided into six groups: (1) life-long vegetarian, (2) became vegetarian at age 1–9 years, (3) became vegetarian at age 10–14 years, (4) became vegetarian at age 15–19 years, (5) became vegetarian at age ≥20 years and (6) non-vegetarian. In the analyses, persons who became vegetarian at age ≥20 years were used as the reference group because most people have stopped growing by age 20 and any growth thereafter is likely to be minimal.

Anthropometry and age at menarche

Body height was reported in feet and inches or in centimetres; data reported in feet and inches were converted to centimetres. Body weight was reported in stones and pounds or in kilograms; data reported in stones and pounds were converted to kilograms. The validity of self-reported height and weight was previously evaluated in a sample of 4808 EPIC-Oxford participants in whom height and weight was both self-reported and measured by a nurse⁸. This study showed that self-reported and measured height and weight respectively were highly correlated ($r > 0.9$). However, height was overestimated by a mean of 1.23 cm in men and 0.60 cm in women and the extent of overestimation was greater in older men and women, shorter men and heavier women. Weight was underestimated by a mean of 1.85 kg in men and 1.40 kg in women and in both men and women there was a trend towards greater underestimation with increasing weight. In the current study, self-reported height and weight was calibrated by using predictive equations derived from the previous validation study using self-reported height, self-reported weight and age group as the predictor variables; the equations are given in the Appendix. BMI was calculated as weight in kilograms divided by the square of height in metres. Information on age at menarche was obtained from the women's answer to the question 'How old were you when you had your first menstrual period?'

Confounding variables

Information on age, ethnicity and age left school were obtained through the questionnaire.

Statistical analysis

The associations between study group and height, age at menarche, weight and BMI were investigated in men and women separately using analysis of variance, adjusting for

Table 1 Characteristics of the participants

	Men	Women
<i>n</i>	10 242	35 720
Age (years)	46.2 ± 15.1	43.2 ± 14.2
Ethnic group		
White	9968 (97.3)	35 066 (98.2)
Non-white	274 (2.7)	654 (1.8)
Age left school (years)		
< 16	1674 (16.3)	5404 (15.1)
16	2664 (26.0)	10 275 (28.8)
17	1569 (15.3)	5767 (16.2)
≥ 18	4335 (42.3)	14 274 (40.0)
Diet group		
Life-long vegetarian	125 (1.2)	265 (0.7)
Became vegetarian at age 1–9 years	76 (0.7)	264 (0.7)
Became vegetarian at age 10–14 years	121 (1.2)	1077 (3.0)
Became vegetarian at age 15–19 years	564 (5.5)	2332 (6.5)
Became vegetarian at age ≥20 years	3122 (30.5)	8137 (22.8)
Non-vegetarian	6234 (60.9)	23 645 (66.2)
Height (cm)	176.7 ± 6.5 (<i>n</i> = 9964)	163.7 ± 5.9 (<i>n</i> = 34 810)
Age at menarche (years)	–	12.9 ± 1.5 (<i>n</i> = 35 270)
Body weight (kg)	77.6 ± 11.6 (<i>n</i> = 9964)	64.4 ± 10.9 (<i>n</i> = 34 810)
Body mass index (kg m ⁻²)	24.8 ± 3.3 (<i>n</i> = 9963)	24.0 ± 3.9 (<i>n</i> = 34 809)

Values are mean ± standard deviation except for ethnic group, age left school and diet group, where they are *n* (%).

age (categorised as 5-year age bands), ethnic group (white/non-white) and age left school (<16, 16, 17 and ≥ 18 years). Adjusted arithmetic means of the anthropometric variables and age at menarche together with their 95% confidence intervals were calculated from the fitted values arising from mathematically equivalent multiple linear regression models. The means in study groups 1–4 and 6 were compared with the mean in group 5 (became vegetarian at age ≥ 20 years) using standard *t*-tests arising from the regression models. Statistical significance of heterogeneity in means across the study groups was assessed using *F*-tests arising from the analysis of variance tables. The statistical power to detect a difference in height of 1 cm between life-long vegetarians and subjects who became vegetarian at age ≥ 20 years was calculated using the STATA command 'sampsi', assuming sample sizes equal to the actual numbers of vegetarians in the two categories, a common standard deviation equal to the overall standard deviation in height and a type I error of 5% ($\alpha = 0.05$). All analyses were performed using version 8.1 of the STATA statistical package (Stata Statistical Software, Release 8.0, 2003; Stata Corporation, College Station, TX, USA).

Results

Approximately 10 000 men and 36 000 women were included in the study (Table 1). A small minority of the subjects were classified as non-white ($n = 928$). The proportions of vegetarians were 39% ($n = 4008$) in men and 34% ($n = 12 075$) in women. The numbers of life-long vegetarians were 125 men and 265 women; the majority of the vegetarians became vegetarian as adults. The median ages in the six diet groups in men were 47, 42, 30, 30, 41 and 48 years, respectively, and in women 43, 33, 25, 27, 39

and 45 years, respectively. The prevalence of overweight and obesity among the participants was relatively low: 36.6% of the men and 23.9% of the women had a BMI between 25 and $<30 \text{ kg m}^{-2}$ and 6.1% of the men and 7.3% of the women had a BMI $\geq 30 \text{ kg m}^{-2}$.

Overall, there was a statistically significant heterogeneity in mean height between the study groups in women, but not in men (Table 2). In both men and women, non-vegetarians were 0.3 cm taller than persons who became vegetarian at age 20 years and above ($P < 0.05$ and $P < 0.001$, respectively). In comparisons of the vegetarian groups (i.e. excluding the non-vegetarians from the analyses), no statistically significant heterogeneities in mean height were seen. In men and women, there were no significant differences in mean height between life-long vegetarians and subjects who became vegetarian at age ≥ 20 years. The statistical power to detect a difference of 1.0 cm between these groups was 0.76 in women and 0.38 in men.

There was no significant difference in mean age at menarche between life-long vegetarian women and women who became vegetarian at age ≥ 20 years (Table 2). However, mean age at menarche was lower (-0.2 years) in women who became vegetarian at age 10–14 years and higher ($+0.1$ years) in non-vegetarian women compared with women who became vegetarian at age ≥ 20 years ($P < 0.01$ in each case).

In both men and women there were no significant differences in mean weight or BMI between life-long vegetarians and subjects who became vegetarian at age ≥ 20 years (Table 3). Men who became vegetarian at age 1–9 years and non-vegetarian men were on average 3.2 kg and 3.0 kg heavier, respectively, than men who became vegetarian at age ≥ 20 years ($P < 0.05$ and $P < 0.001$, respectively). This was also reflected in their mean BMI,

Table 2 Height and age at menarche by sex and diet group

	Men			<i>P</i> -value‡	Women			<i>P</i> -value‡
	<i>n</i>	Mean†	95% CI		<i>n</i>	Mean†	95% CI	
Height (cm)								
Life-long vegetarian	122	176.3	(175.2–177.5)	0.12 (0.70)	257	163.1	(162.4–163.8)	<0.001 (0.24)
Vegetarian at age 1–9 years	71	176.1	(174.7–177.6)		257	164.2	(163.5–164.9)	
Vegetarian at age 10–14 years	118	176.9	(175.8–178.1)		1042	163.6	(163.2–164.0)	
Vegetarian at age 15–19 years	538	176.2	(175.6–176.7)		2226	163.6	(163.3–163.8)	
Vegetarian at age ≥ 20 years	3012	176.5	(176.3–176.8) ^R		7880	163.5	(163.4–163.6) ^R	
Non-vegetarian	6103	176.8	(176.7–177.0)*		23 148	163.8	(163.7–163.9)***	
Age at menarche (years)								
Life-long vegetarian	–				258	13.0	(12.8–13.1)	<0.001 (0.02)
Vegetarian at age 1–9 years	–				258	12.8	(12.6–13.0)	
Vegetarian at age 10–14 years	–				1067	12.7	(12.6–12.8)**	
Vegetarian at age 15–19 years	–				2313	12.8	(12.8–12.9)	
Vegetarian at age ≥ 20 years	–				8053	12.8	(12.8–12.9) ^R	
Non-vegetarian	–				23 321	12.9	(12.9–12.9)**	

CI – confidence interval.

† Adjusted for age, ethnicity and age left school.

‡ *P*-values for heterogeneity between the means in the study groups, including and, in parentheses, excluding the non-vegetarians.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$ for a significantly different mean compared with the mean in the group of subjects becoming vegetarian at age ≥ 20 years (reference group, ^R).

Table 3 Body weight and body mass index by sex and diet group

	Men			<i>P</i> -value‡	Women			<i>P</i> -value‡
	<i>n</i>	Mean†	95% CI		<i>n</i>	Mean†	95% CI	
Body weight (kg)								
Life-long vegetarian	122	75.5	(73.5–77.6)	<0.001 (0.07)	257	63.1	(61.7–64.4)	<0.001 (0.05)
Vegetarian at age 1–9 years	71	79.0	(76.3–81.6)*		257	64.3	(63.0–65.6)*	
Vegetarian at age 10–14 years	118	76.4	(74.3–78.5)		1042	63.8	(63.2–64.5)*	
Vegetarian at age 15–19 years	538	75.3	(74.3–76.3)		2226	63.1	(62.6–63.5)	
Vegetarian at age ≥ 20 years	3012	75.7	(75.3–76.3) ^R		7880	62.9	(62.6–63.1) ^R	
Non-vegetarian	6103	78.8	(78.5–79.1)***		23 148	65.0	(64.9–65.2)***	
Body mass index (kg m ⁻²)								
Life-long vegetarian	122	24.2	(23.7–24.8)	<0.001 (0.02)	257	23.7	(23.2–24.2)	<0.001 (0.06)
Vegetarian at age 1–9 years	71	25.4	(24.7–26.2)**		257	23.9	(23.4–24.3)	
Vegetarian at age 10–14 years	118	24.4	(23.8–25.0)		1042	23.8	(23.6–24.1)**	
Vegetarian at age 15–19 years	538	24.2	(23.9–24.5)		2226	23.6	(23.4–23.7)	
Vegetarian at age ≥ 20 years	3011	24.3	(24.2–24.4) ^R		7880	23.5	(23.4–23.6) ^R	
Non-vegetarian	6103	25.2	(25.1–25.3)***		23 147	24.2	(24.2–24.3)***	

CI – confidence interval.

† Adjusted for age and ethnicity.

‡ *P*-values for heterogeneity between the means in the diet groups, including and, in parentheses, excluding the non-vegetarians.**P* < 0.05, ***P* < 0.01, ****P* < 0.001 for a significantly different mean compared with the mean in the group of subjects becoming vegetarian at age ≥ 20 years (reference group, ^R).

where the corresponding differences were 1.2 kg m⁻² (*P* < 0.01) and 0.9 kg m⁻² (*P* < 0.001), respectively. Compared with women who became vegetarian at age ≥ 20 years, higher mean body weights were seen in women who became vegetarian at age 1–9 (+1.5 kg, *P* < 0.05), in women who became vegetarian at age 10–14 (+1.0 kg, *P* < 0.05) and in non-vegetarian women (+2.2 kg, *P* < 0.001). For BMI, corresponding differences were seen in women who became vegetarian at age 10–14 years (+0.3 kg m⁻², *P* < 0.01) and in non-vegetarian women (+0.7 kg m⁻², *P* < 0.001).

We also performed the analyses using non-calibrated self-reported height and weight and differences in height, weight and BMI between the groups were nearly identical to those obtained when the calibrated values were used (results not shown).

Discussion

An appropriately planned vegetarian diet is considered to be nutritionally adequate for all stages of the life cycle³. Indeed, the beneficial role of plant-based diets in the prevention of chronic diseases such as obesity, cardiovascular disease, diabetes and cancer has gained increasing attention^{3,9}. However, epidemiological data on growth and development in vegetarians are still sparse. Studies on children and adolescents have generally found that optimal growth can be achieved by a vegetarian diet (which includes egg and dairy products)^{4,5,10–12} as well as a vegan diet (which excludes all foods of animal origin)^{13–15}, whereas a restricted macrobiotic diet (which is based on a limited range of plant foods) does not meet the nutritional needs of infants and children^{16–20}; see Hebbelink and Clarys²¹ for an extensive review. However, data on height in adult long-term vegetarians

are lacking. It is also not clear whether age at menarche is affected by a vegetarian diet. In the current study, the large number of vegetarians allowed us to specifically look at the effects of being a vegetarian since birth, which, to our knowledge, has not been possible in previous studies.

Our study showed no significant difference in adult height between life-long vegetarians and subjects who became vegetarian at age 20 or above. Although this is the largest study on growth in vegetarians to date, the number of life-long vegetarians was relatively small and the statistical power to detect a difference of 1.0 cm between these groups was 0.76 in women and 0.38 in men. Therefore, the possibility of small differences in height between these groups cannot be excluded, particularly for the men. To our knowledge, only one previous study has examined height in adult vegetarians. In that study of Flemish subjects, of whom a majority (72%) were life-long vegetarians, vegetarian men and women aged 18–30 years were non-significantly shorter than a reference group¹¹; however, the numbers of adult vegetarians were very small (*n* = 8 and *n* = 11, respectively). In the current study, non-vegetarian men and women were slightly taller (+0.3 cm) than subjects who became vegetarian at age ≥ 20 years. There is no obvious reason why people who become vegetarian as adults, when their growth has essentially stopped, should be shorter than non-vegetarians. One possible explanation is differential misreporting of height between vegetarians and non-vegetarians. Unknown confounding factors may also account for the difference.

Age at menarche is known to be partly determined by height and weight^{22–24}, which in turn may be affected by diet. However, after adjusting for body size, associations between dietary factors, particularly the intake of fibre, and age at menarche have been found by some

studies^{23,25,26} but not all^{22,24,27}. In the current study, there was no difference in age at menarche between life-long vegetarians and women who became vegetarian at age 20 or above. The findings are consistent with a smaller study in which no difference in age at menarche between vegetarian Seventh-Day Adventists and non-vegetarian girls was observed²⁸.

There were no difference in obesity, assessed as adult body weight and BMI, between life-long vegetarians and subjects who became vegetarian at age 20 or above. Some differences were noticed for the other groups. That vegetarians are slimmer than non-vegetarians has been demonstrated in other studies^{29–31}. Data on BMI in the non-vegetarians, vegetarians and vegans in EPIC–Oxford have been reported and discussed in detail elsewhere²⁹; the differences in BMI between the diet groups remained after adjustment for several lifestyle factors, and were partly explained by differences in the intakes of protein and fibre²⁹. More unexpected is the finding of a higher mean BMI among subjects who became vegetarian during childhood (men) or adolescence (women) compared with subjects who became vegetarian as adult. The difference was particularly notable among the men and whether this is due to chance or explained by other factors is not known.

In the current study, the majority of the subjects were vegetarians, who include dairy and egg products in their diet. The number of vegans, who exclude all animal foods, was too small to allow for a separate analysis of this group and the effects of a life-long vegan diet therefore remain to be studied. Multigenerational effects of vegetarian diets also merit further investigation.

In conclusion, this study indicates that growth and development, assessed as adult height and age at menarche, are not affected by life-long adherence to a vegetarian diet. Adult BMI is lower in vegetarians than non-vegetarians, but does not differ between life-long vegetarians and people who become vegetarian when adult.

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Appendix

Self-reported height and weight were calibrated using predictive equations with self-reported height (sr-height), self-reported weight (sr-weight) and age group (<50, 50–59, ≥60 years) as the predictor variables.

Men

Height = $c + 0.9073 \times \text{sr-height} + 0.0205 \times \text{sr-weight}$,

where $c = 14.02$ if age <50 years, $c = 13.64$ if age 50–59 years and $c = 13.02$ if age ≥60 years.

Weight = $c + 0.0182 \times \text{sr-height} + 1.0073 \times \text{sr-weight}$,

where $c = -2.01$ if age <50 years, $c = -1.93$ if age 50–59 years and $c = -1.88$ if age ≥60 years.

Women

Height = $c + 0.8548 \times \text{sr-height} - 0.0006 \times \text{sr-weight}$,

where $c = 23.65$ if age <50 years, $c = 23.08$ if age 50–59 years and $c = 22.35$ if age ≥60 years.

Weight = $c + 0.0033 \times \text{sr-height} + 1.0092 \times \text{sr-weight}$,

where $c = 0.21$ if age <50 years, $c = 0.26$ if age 50–59 years and $c = 0.32$ if age ≥60 years.