Dietary pattern trajectories across adolescence and early adulthood and their associations with childhood and parental factors

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ABSTRACT

Background: Although adolescent dietary patterns tend to be of poor quality, it is unclear whether dietary patterns established in adolescence persist into adulthood.

Objectives: We examined trajectories across adolescence and early adulthood for 2 major dietary patterns and their associations with childhood and parental factors.

Methods: Using data from the Western Australian Pregnancy Cohort (Raine Study), intakes of 38 food groups were estimated at ages 14, 17, 20 and 22 y in 1414 participants using evaluated FFQs. Using factor analysis, 2 major dietary patterns (healthy and Western) were consistently identified across follow-ups. Sex-specific group-based modeling assessed the variation in individual dietary pattern *z* scores to identify group trajectories for each pattern between ages 14 and 22 y and to assess their associations with childhood and parental factors.

Results: Two major trajectory groups were identified for each pattern. Between ages 14 and 22 y, a majority of the cohort (70% males, 73% females) formed a trajectory group with consistently low *z* scores for the healthy dietary pattern. The remainder had trajectories showing either declining (27% females) or reasonably consistent healthy dietary pattern *z* scores (30% males). For the Western dietary pattern, the majority formed trajectories with reasonably consistent average scores (79% males, 81% females) or low scores that declined over time. However, 21% of males had a trajectory of steady, marked increases in Western dietary pattern scores over time. A lower maternal education and higher BMI (in kg/m^2) were positively associated with consistently lower scores of the healthy dietary pattern. Lower family income, family functioning score, maternal age, and being in a single-parent family were positively related to higher scores of the Western dietary pattern.

Conclusions: Poor dietary patterns established in adolescence are likely to track into early adulthood, particularly in males. This study highlights the transition between adolescence and early adulthood as a critical period and the populations that could benefit from dietary interventions. *Am J Clin Nutr* 2021;113:36–46.

Keywords: dietary patterns, tracking, trajectories, Raine Study, adolescence, early adulthood

Introduction

The transition from adolescence to young adulthood brings about increased autonomy, leading to milestones in independence, such as entering the workforce or formal study, generating personal income, or changes in living arrangements (1). These factors can have lasting implications for health behaviors, particularly dietary intake (2, 3). Poor diet quality is common during adolescence (4, 5) and has been linked with the early onset of chronic disease risk factors such as obesity and a high abdominal waist circumference (6, 7). During young adulthood, poor lifestyle behaviors may become embedded (8), and this is a high risk period for excess weight gain (9, 10). Young adulthood also often heralds first-time parenthood. Therefore, the transition from adolescence to young adulthood is a critical period for interventions to reduce chronic disease risk and prevent

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Supplemental Tables 1–5 and Supplemental Materials are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

Data described in the manuscript will be made available upon request from rainestudy.org.au. Restrictions apply to the availability of these data; however, requests may be made through study management.

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Abbreviations used: BIC, Bayesian information criterion; CSIRO, Commonwealth Scientific and Industrial Research Organisation; DQESV2, Dietary Questionnaire for Epidemiological Studies; GFS, General Functioning Scale; Raine Study, Western Australian Pregnancy Cohort; SES, socioeconomic status.

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the transgenerational cycle of obesity and related diseases, such as diabetes and cardiovascular disease (8).

The health of adolescents and young adults (aged 18–34 y) is frequently overlooked by researchers and policymakers (11, 12). To date, our understanding of whether dietary intake is maintained or subject to change between adolescence and adulthood is limited (13–15). A better understanding of dietary patterns and how they track is required to inform public health policy and interventions to support healthy eating across this important life stage (13, 14). A small number of studies have shown that empirically derived dietary patterns identified using methods such as factor analysis or reduced rank regression may be stable during childhood and adolescence (16–19); however, few studies to date have tracked dietary pattern trajectories across adolescence and into adulthood (16, 20).

The Western Australian Pregnancy Cohort (Raine) Study began in 1989 with 2900 pregnant women (Generation 1) (21). A total of 2868 infants (Generation 2) born to these women have been repeatedly followed up from birth. Two empirically derived dietary patterns were identified in Generation 2 at ages 14 and 17 y using factor analysis: a healthy and a Western dietary pattern (22). In this cohort, a higher score for the Western dietary pattern has been positively associated with nonalcoholic fatty liver disease (23), markers of the metabolic syndrome (24), mental health problems (25), developmental disorders (26), cognitive performance (27), and lifestyle and family psychosocial factors (22) during adolescence.

Using extended follow-up data from this contemporary cohort, we report trajectories in Western and healthy dietary pattern scores at 4 time points (14, 17, 20, and 22 y) in Generation 2 to examine whether dietary patterns established during adolescence persist into adulthood. We also report on the modifiable antecedents of these trajectories.

Methods

Study population

The Raine Study has been described in detail elsewhere (28). In brief, the Raine Study is a multigenerational cohort study that began with the recruitment of 2900 pregnant women (Generation 1) through the public antenatal clinic and local private clinics in Perth, Western Australia, between 1989 and 1991 for an initial study to investigate the effects of repeated ultrasounds on fetal growth (21). Their 2868 births (Generation 2) have been followed up since birth and approximately biennially thereafter.

Dietary assessments

This analysis used comprehensive dietary data collected from Generation 2 at ages 14, 17, 20, and 22 y. At ages 14 and 17 y, a semiquantitative FFQ designed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australia was administered to assess usual food and nutrient intakes (29). The FFQ collected information on usual frequency of consumption and serving sizes (in household units) of 227 food and beverage items. Nutrient intakes estimated by the CSIRO FFQ have been shown to be comparable with those estimated using a 3-d diet record at age 14 y in this cohort (30).

Because the CSIRO FFQ was not available for use at the 20- and 22-y follow-ups, usual dietary intake at ages 20 and 22 y was estimated using the 74-item semiquantitative Dietary Questionnaire for Epidemiological Studies (DQESV2) FFQ, developed by the Cancer Council of Victoria, Australia (31). The DQESV2 FFQ has been found to be reproducible and suitable for ranking respondents according to their estimated nutrient intakes and comparable to the CSIRO FFQ (32, 33). The DQESV2 collects information on the usual frequency of consumption of food and drinks and also usual serving sizes using pictorial examples.

Unlike the CSIRO FFQ, the DQESV2 FFQ did not include a comprehensive list of beverages; therefore, a semiquantitative beverage questionnaire was administered at ages 20 and 22 y. The DQESV2 FFQ included fruit juice, flavored milk, milk, and alcohol intakes. The semiquantitative beverage questionnaire listed other beverages that were included in the CSIRO FFQ, including water, “fizzy drink,” diet “fizzy drink,” energy drink, diet energy drink, tea, herbal tea, green tea, instant coffee, and ground coffee. Estimates of usual serving size were collected (with examples of typical serving sizes provided) along with the usual frequency of consumption.

The FFQs were completed with assistance from a parent or caregiver at age 14 y (2003–2006) and by the study respondents at ages 17 y (2006–2009), 20 y (2010–2012), and 22 y (2012–2014). All FFQs were checked by a research nurse, and missing and unclear responses were corrected with the study respondent at the time of their physical assessment. Australian Food Composition Tables were used to estimate usual nutrient intakes and total energy intake (22).

Food groupings

To conduct dietary pattern analyses, all food and beverage items listed in the FFQs were assigned to 38 predefined major food groups based on nutrient profile and culinary usage (22). Although the 2 FFQs were highly similar, a small number of food groups in the CSIRO FFQ were not captured by the DQESV2 FFQ, including meat-based mixed dishes, milk-based dishes, soups, sauces, and dried fruit.

Dietary patterns

The Raine Study healthy and Western dietary patterns have been described in detail previously (22). In brief, all 38 major food groups were entered into a factor analysis and varimax rotation applied, to achieve uncorrelated factors or dietary patterns, using PROC FACTOR in SAS (SAS Institute). The resulting factor solution identified 2 major dietary patterns that explained the greatest amount of total variance in food group intakes (21.5% in total) (34). The total variance of the food intakes explained by the individual dietary patterns was 13% for the Western dietary pattern and 9% for the healthy dietary pattern (34), which is similar to other comparable studies (35–37). Each participant received a z score for the healthy and the Western dietary pattern (calculated using PROC SCORE, SAS), which indicated how close their reported dietary intake corresponded with the pattern, relative to the rest of the study sample (z score mean = 0; SD = 1).

For each dietary pattern, the factor solution generated factor loadings for each food group, indicating their "weighting" or contribution to each dietary pattern (22). Foods with a factor loading greater than an absolute value of 0.30 were considered the most influential in each pattern. At age 14 y, the healthy dietary pattern was characterized by positive factor loadings for whole grain cereals; fresh fruit; legumes; steamed, grilled, or canned fish; and all vegetables, except potatoes (22). As such, higher intakes of these foods increase the healthy dietary pattern score and vice versa. The Western dietary pattern consisted of positive factor loadings for takeaway foods, red meats, processed meats, full-fat dairy products, fried potato, refined grains, soft drinks, confectionery, and chips (22). Greater intakes of these food groups, therefore, increase the Western dietary pattern score and vice versa. This pattern showed strong correlations with intake of energy, total fat, saturated fat, cholesterol, and refined sugar (22). Healthy and Western dietary pattern z scores estimated using the CSIRO FFQ have been shown to be comparable to those estimated using a 3-d diet record in this cohort at age 14 y (30).

The exploratory factor analysis described previously was repeated using food group intakes estimated at ages 17, 20, and 22 y. This identified 2 major dietary patterns consistent with the healthy and Western dietary patterns identified at age 14 y, at each age. Apart from some minor variations, the factor loadings were similar across ages 14, 17, 20, and 22 y (**Supplemental Table 1**). Because very similar healthy and Western dietary patterns were observed over time at the population level (i.e., magnitude and direction), a longitudinal analysis of z scores for the healthy and Western dietary patterns was deemed appropriate. However, to score individuals for exactly the same dietary patterns using the same scoring weights over time, applied dietary pattern scores were estimated. These were calculated by applying the factor scoring coefficients for each food group identified at age 14 y to dietary intakes at ages 17, 20, and 22 y (confirmatory analysis) using PROC SCORE in SAS. Therefore, any observed changes in z scores are relative to those estimated at age 14 y. The 5 food groups not captured by DQESV2 FFQ (meat-based mixed dishes, milk-based dishes, soups, sauces, and dried fruit) did not load strongly on either pattern at age 14 or 17 y (see Supplemental Table 1) and were therefore excluded from the confirmatory factor analyses. Despite this difference, exploratory and applied dietary pattern scores were highly correlated ($r > 0.94$).

Covariates

Height was measured using a Holtain stadiometer without shoes and weight was recorded using a Wedderburn digital chair scale with light clothing to calculate BMI (in kg/m^2) at age 14 y. Self-reported physical activity levels at age 14 y were estimated by asking the respondents to report the number of times they exercised enough to sweat when they were not at school (excluding compulsory school physical education sessions). Respondents were asked to choose 1 option from 5 categories ranging from exercising ≤1 per month to exercising every day. These data were used to create an ordinal variable: low (exercising 1 time per month), medium (exercising 1–3 times per week), and high (exercising ≥4 times per week). In this cohort, self-reported physical activity levels have been shown to be highly correlated with an aerobic fitness data measured objectively using a Physical Working Capacity-170 on an ergometer bicycle at age 14 y (24). However, only self-reported physical activity was used in this analysis because more respondents completed this questionnaire than the ergometer bicycle test.

Maternal factors during prepregnancy and pregnancy, such as maternal body weight, may have a direct or indirect (e.g., as a lifestyle marker) influence on the development of childhood obesity and other metabolic risks (38). Information on maternal self-reported prepregnancy weight was collected at enrollment into the study (∼18 weeks of gestation). Height was measured at the first physical assessment (16–20 weeks of gestation). Maternal age at child birth was recorded upon birth of the study child.

Because several studies have suggested that parental socioeconomic status (SES) is closely associated with children's dietary intake, we investigated the potential role of SES in determining an individual's dietary pattern trajectory (39–42). A standardized questionnaire was used to obtain information on parental SES at age 14 y. This included categories of maternal education represented by highest school year (<10 y, 10–12 y, and >12 y), family income in Australian dollars (≤35,000, >35,000–50,000, >50,000–70,000, >70,000–104,000, and >104,000), and family structure (2-parent or single-parent, with de facto parents or partners considered as a 2-parent family structure). Family functioning [General Functioning Scale (GFS)] was estimated using the McMaster Family Assessment Device at age 14 y (43). The GFS comprised questions on family communication, affective responsiveness, and behavior control, with higher scores representing better family functioning. The GFS scores were classified into quartiles [0 = quartile 1 (scores ≤25), 1 = quartile 2 (scores between 26 and 28), 2 = quartile 3 (scores between 29 and 33), and 3 = quartile 4 (scores between 34 and 39)]. Finally, parental smoking status (yes or no) was recorded at age 14 y and assessed as a potential predictor of dietary pattern trajectories.

Ethics approval and consent to participate

All data collection for the Raine Study was conducted in accordance with the Australian National Health and Medical Research Council Guidelines for Ethical Conduct in Human Research and was approved by the ethics committees of King Edward Memorial Hospital for Women and Princess Margaret Hospital for Children, Perth, Western Australia. Written informed consent was obtained from both the primary caregivers (at ages 14 and 17 y) and study respondents (at ages 20 and 22 y).

Statistical analyses

Characteristics of the eligible study sample at age 14 y ($n = 2424$) and individuals included in the trajectory analyses—that is, individuals with ≥2 outcome measures ($n = 1377$)—were summarized (28). Summary statistics are provided for healthy and Western dietary pattern scores at each time point, with means and SDs, medians and ranges, as well as missing numbers (**Supplemental Table 2**).

Group-based trajectory modeling was used to assess variation in the developmental course of z scores for both dietary patterns reflecting changes in the consumption of foods loading onto each of 2 dietary patterns over time. This modeling was undertaken separately for males and females, using PROC TRAJ in SAS version 9.4 (see **Supplemental Materials** composed of SAS coding and annotated output and an Excel data file). PROC TRAJ is a procedure that estimates a discrete mixture model for the clustering of longitudinal data (44). Groups may either represent distinct subpopulations or be components of a discrete approximation for a potentially complex data distribution (45). The decision to use group-based trajectories, as opposed to competing approaches such as growth mixture modeling, was based on the wide range of individual trajectory shapes found in the data. Growth mixture modeling describes individual variability from a single population mean trend, whereas group-based trajectory modeling assumes multiple subpopulation mean trends. The latter methodology allows for a wider range of shapes for the trajectories and so is the appropriate choice. These methods have also been shown to be effective in other studies on data of a similar nature that have followed the same approach (44).

Z scores for healthy and Western dietary patterns from each respondent were used as dependent variables, and their ages at each follow-up were applied as independent variables (note that although there is small variation in the exact ages at each follow-up, PROC TRAJ has the capability to handle time-unstructured data). Because group-based trajectory modeling operates by fitting a line that best approximates population change over time, there must be ≥2 data points per person. Individuals who did not have ≥2 outcome measurements were removed from the data prior to model fitting. It was assumed that these individuals had observations missing at random and so no further investigation was conducted. The underlying data distribution chosen for the modeling procedure was the censored normal distribution. This distribution is the most sensible choice given that the dependent variables are themselves z scores and are inherently continuous. Lower and upper bounds were chosen to lie outside the range of observed values to allow for the modeling of all observations.

Trajectory models were fitted according to established methods in a 2-stage approach (44). The first stage of model selection is to choose the number of groups to fit. Models were fit containing 2, 3, 4, and 5 groups, with a cubic polynomial for each. No more than 5 groups were tested because the potential for appropriate interpretability severely reduces with more groups. The number of groups was determined based on their interpretability and using the Bayesian information criterion (BIC) approach. The degree of each polynomial trajectory was determined by statistical significance using backward selection. Based on the results of the trajectory modeling, 2 groups of trajectories for each dietary pattern (and sex) had the minimum BIC and thus the best model fit.

After establishing the number of groups and degrees of polynomials, a set of fixed (time-invariant) covariates (each measured at baseline) were included in the models. The following fixed covariates were considered: maternal education level, maternal age at birth, maternal prepregnancy BMI, whether the parents smoked, whether the father lives with the family, family income, family functioning status, BMI, and self-reported physical activity. Backwards selection based on statistical significance was used to determine the existence of relations between the fixed covariates and group membership. All analysis was carried out using SAS version 9.4.

Results

Baseline characteristics

The number of participants who provided data at each follow-up is described in **Figure 1**. **Table 1** presents characteristics of study participants who provided data at the 14-y follow-up (n = 1605) as well as those with dietary data for ≥2 outcome measurements (1377 individuals, 47.3% males), who were then subsequently included in the trajectory modeling. Compared with participants who provided data at 14 y, those included in the trajectory modeling were more likely to be female, to live in 2-parent families, have a family income >AUD$70,000, and have parents who did not smoke (Table 1).

Dietary patterns

Summary statistics for the healthy and Western z scores over each follow-up are shown in Supplemental Table 2. The distribution of the mean, median, and ranges of dietary pattern z scores was comparable across the ages between the eligible cohort at 14 y and those with at least 2 follow-ups. A reduction in mean z scores was observed for both healthy and Western dietary patterns with increasing age.

Healthy dietary pattern trajectories

Figure 2 (top) presents the 2-group trajectory solution obtained for the healthy dietary pattern. Both males and females formed a trajectory group with consistently below-average healthy pattern z scores during the follow-up period (group 1; black line); these groups included the majority of males (70%) and females (73%). The remaining 30% of males (group 2; gray line) had above-average healthy dietary pattern z scores throughout, which showed small declines from age 16 y onward. The remaining 27% of females formed a trajectory group (group 2; gray line) showing well above-average healthy dietary pattern z scores; however, these declined considerably between ages 16 and 22 y.

Western dietary pattern trajectories

Figure 2 (bottom) shows the 2-group trajectory solution for the Western dietary pattern. The majority of males (79%) had relatively stable, close to average z scores for this pattern across all ages (group 1; black line). The remaining males (21%) had a trajectory of Western dietary pattern z scores that increased substantially with age (group 2; gray line). In females, the majority of females (81%) formed a trajectory group with below-average Western pattern scores that declined over time (group 1; black line). A small proportion of females (19%) showed a less stable trajectory of Western pattern z scores that initially declined up to age 17 y but increased thereafter (group 2; gray line). See **Supplemental Tables 3** and **4** for BIC values for all the models considered during model selection and statistical significance (P values) of the coefficients related to the shape of the trajectory models, respectively.

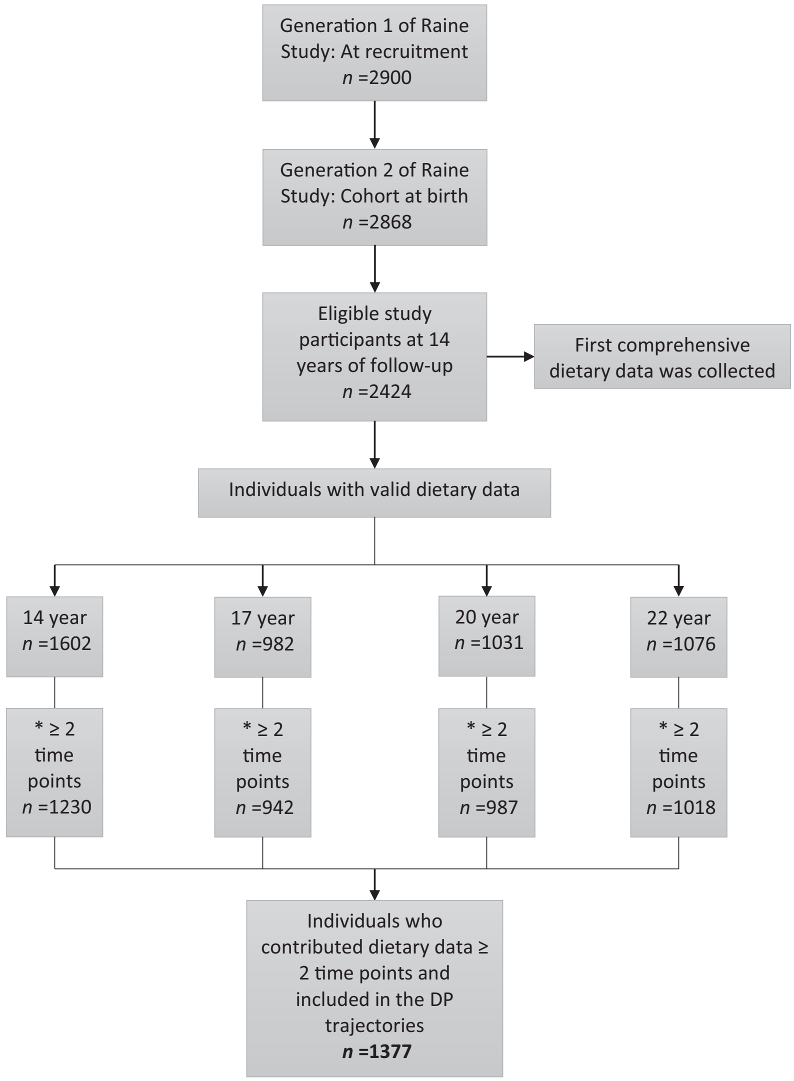

FIGURE 1 Flowchart of the Raine Study participation. Asterisks indicate individuals who contributed dietary data at ≥2 time points. DP, dietary pattern.

Factors associated with the healthy dietary pattern

In females, the likelihood of being classified into group 1 (having consistently lower healthy pattern *z* scores during the follow-up) compared to group 2 decreased with higher maternal education level (OR: 0.26; 95% CI: 0.10, 0.66 for 10–12 y of education; OR: 0.09; 95% CI: 0.04, 0.23 for >12 y of education; compared with <10 y of education) (**Table 2**). For males, the odds of membership in group 1 (having consistently lower healthy pattern *z* scores during the follow-up) compared with group 2 increased with a higher maternal prepregnancy BMI (OR: 1.12; 95% CI: 1.03, 1.22) and decreased with higher maternal education level (OR: 0.20; 95% CI: 0.09, 0.48 for >12 y of education) (Table 2).

Factors associated with the Western dietary pattern

In females, the odds of being in group 1, which showed a decline in Western pattern *z* scores during the follow-up period, increased with a higher maternal age at birth (OR: 1.07; 95% CI: 1.02, 1.12), with a higher family functioning score (OR: 1.66; 95% CI: 1.30, 2.13), and with a family income >AUD$104,000 (OR: 9.16; 95% CI: 2.17, 38.74) compared with group 2 (with increasing Western pattern scores) (Table 2). In males, the odds of being in group 1 (relatively stable *z* scores) increased with a higher maternal age at birth (OR: 1.06; 95% CI: 1.01, 1.12) and were higher if they were from a 2-parent family (OR: 1.35; 95% CI: 1.04, 1.75) compared with group 2 (Table 2).

Discussion

Two consistent dietary patterns were observed in this cohort at ages 14, 17, 20, and 22 y: a healthy and a Western dietary pattern. Longitudinal modeling of individual dietary pattern *z* scores identified 2 major trajectory groups for each dietary pattern, across adolescence and into adulthood. A majority of males and females fell into a trajectory of consistently below-average healthy pattern scores. The remaining males and females had less stable trajectories in healthy pattern scores that, although

TABLE 1 Characteristics of the individuals included in dietary trajectory analysis, Raine Study

	Participants who completed 14-y follow-up		Individuals included in dietary trajectory analysis[1]	
Characteristic	*n*	Counts (%) or mean ± SD	*n*	Counts (%) or mean ± SD
Sex	1605		1377	
Female		783 (48.8)		725 (52.7)
Male		822 (51.2)		652 (47.3)
BMI at 14 y, kg/m^2	1605	21.3 ± 4.2	1175	21.1 ± 4.1
Self-reported physical activity at 14 y	1602		1172	
≤1 time per month		146 (9.1)		104 (8.9)
1 time per week		325 (20.3)		238 (20.3)
2–3 times per week		606 (37.8)		462 (39.4)
≥4 times per week		525 (32.8)		368 (31.4)
Maternal age at birth, y	1567	29.0 ± 5.8	1348	29.5 ± 5.6
Maternal prepregnancy BMI, kg/m^2	1566	22.4 ± 4.2	1348	22.2 ± 4.1
Maternal education attainment, y	1461		1216	
<10 (minimum schooling)		341 (23.3)		272 (22.4)
10–12 (vocational)		577 (39.5)		479 (39.4)
>12 (degree/diploma)		543 (37.2)		465 (38.2)
Family General Functioning Scale[2]	1500		1246	
0		355 (23.7)		281 (22.6)
1		362 (24.1)		302 (24.2)
2		434 (28.9)		361 (29.0)
3		349 (23.3)		302 (24.2)
Two-parent family structure	1562		1285	
No/deceased[3]		564 (36.1)		405 (31.5)
Yes		998 (63.9)		880 (68.5)
Family income (AUD$)	1539		1262	
≤35,000		379 (24.6)		266 (21.1)
35,001–50,000		246 (16.0)		197 (15.6)
50,001–70,000		302 (19.6)		249 (19.7)
70,001–104,000		339 (22.0)		301 (23.9)
≥104,001		273 (17.8)		249 (19.7)
Parent smoker	1549		1,277	
No		1195 (77.1)		1028 (80.5)
Yes		354 (22.9)		249 (19.5)

[1]Study participants who provided at least 2 dietary assessments between ages 14 and 22 y.
[2]A higher value indicates better family functioning.
[3]Indicates that family is not composed of a 2-parent family structure.

started out well above average, showed modest declines after late adolescence, with this most evident in females. Of most concern was the trajectory in which Western pattern scores showed year-on-year increases from age 16 y onward (in males). Females also showed increases in Western dietary pattern scores in later adolescence.

In terms of dietary quality, these findings suggest that most adolescents do not maintain a healthy dietary pattern over adolescence and into early adulthood. Most adolescents maintained low healthy dietary pattern scores throughout adolescence and into early adulthood. A minority of adolescents (30% males, 27% females) started with above-average healthy dietary pattern scores at age 14 y, but these declined during the course of adolescence and into adulthood (although a later return to healthier habits in early adulthood was suggested). Concerningly, those with above-average Western dietary pattern scores at age 14 y (23% males, 19% females) demonstrated a worsening in diet quality across adolescence and into adulthood, particularly among males. The follow-up at age 17 y showed increases in Western pattern scores (23% males, 19% females) and declines in healthy pattern scores (27% females). Collectively, these findings highlight the stage between adolescence and early adulthood as an important transition period for dietary habits.

Tracking is usually referred to as the consistency in measurement or ranking between ≥2 time points (46). A small number of studies have evaluated the tracking or maintenance of empirical dietary pattern *z* scores between adolescence and young adulthood stage (16, 20), using different methods. For instance, Mikkila et al. (16) reported tracking of "traditional Finnish" and "health-conscious" dietary patterns in the Cardiovascular Risk in Young Finns Study in children (aged 3–12 y) and adolescents (aged 15–18 y). Tracking in this study was assessed according to the proportion of participants remaining in the same quintile for dietary pattern score at 6 and 21 y after baseline. By this definition, tracking was strongest for the traditional Finnish dietary pattern (characterized by high intake of butter, potatoes, and sausages) in the adolescent group (16).

The Canadian Saskatchewan Pediatric Bone Mineral Accrual Study tracked a Western-like dietary pattern characterized by high intakes of refined grains and processed meat from childhood

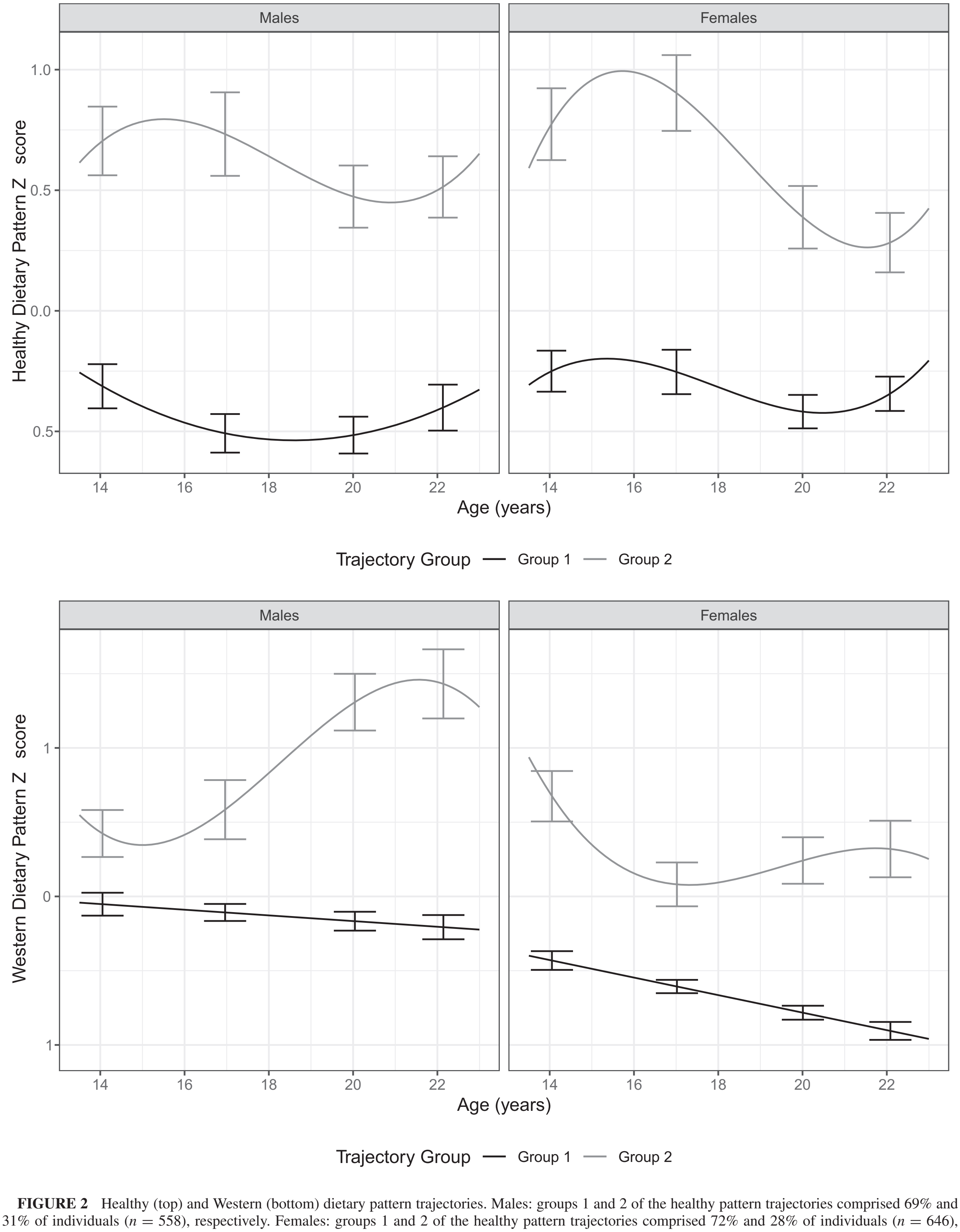

FIGURE 2 Healthy (top) and Western (bottom) dietary pattern trajectories. Males: groups 1 and 2 of the healthy pattern trajectories comprised 69% and 31% of individuals ($n = 558$), respectively. Females: groups 1 and 2 of the healthy pattern trajectories comprised 72% and 28% of individuals ($n = 646$), respectively. Males: groups 1 and 2 of the Western pattern trajectories comprised 77% and 23% of individuals ($n = 597$), respectively. Females: groups 1 and 2 of the Western pattern trajectories comprised 81% and 19% of individuals ($n = 629$), respectively. The error bars indicate 95% CIs around the estimated polynomials at each averaged time of observation.

TABLE 2 Factors associated with dietary pattern trajectories in males and females, Raine Study[1]

	Males			Females		
Healthy dietary pattern trajectories	Group 1 ($n = 392$) count (%) or mean ± SD	Group 2 ($n = 166$) count (%) or mean ± SD	OR[2] (95% CI), P value	Group 1 ($n = 474$) count (%) or mean ± SD	Group 2 ($n = 172$) count (%) or mean ± SD	OR[2] (95% CI), P value
Maternal prepregnancy BMI, kg/m^2	22.4 ± 3.9	21.0 ± 3.0	1.12 (1.03, 1.22), $P = 0.009$	—[3]	—	—
Maternal education attainment, y						
<10 (minimum schooling)	100 (89.29)	12 (10.71)	1	150 (94.34)	9 (5.66)	1
10–12 (vocational)	165 (74.32)	57 (25.68)	0.42 (0.18, 1.02), $P = 0.055$	200 (79.37)	52 (20.63)	0.26 (0.10, 0.66), $P = 0.005$
>12 (degree/diploma)	127 (56.70)	97 (43.30)	0.20 (0.09, 0.48), $P < 0.001$	124 (52.77)	111 (47.23)	0.09 (0.04, 0.23), $P < 0.001$
Missing		94 (14.42)			79 (10.90)	
Western dietary pattern trajectories	Group 1 ($n = 470$) count (%) or mean ± SD	Group 2 ($n = 127$) count (%) or mean ± SD	OR[4] (95% CI), P value	Group 1 ($n = 510$) count (%) or mean ± SD	Group 2 ($n = 119$) count (%) or mean ± SD	OR[4] (95% CI), P value
Family income (AUD$)						
≤35,000	—	—	—	101 (73.19)	37 (26.81)	1
35,001–50,000	—	—	—	76 (73.08)	28 (26.92)	0.96 (0.46, 1.98), $P = 0.901$
50,001–70,000	—	—	—	89 (78.07)	25 (21.93)	1.30 (0.60, 2.80), $P = 0.500$
70,001–104,000	—	—	—	128 (83.12)	26 (16.88)	1.66 (0.81, 3.39), $P = 0.164$
≥104,001	—	—	—	116 (97.48)	3 (2.52)	9.16 (2.17, 38.74), $P = 0.003$
Two-parent family						
No/deceased	105 (22.34)	365 (77.66)	1	—	—	—
Yes	58 (45.67)	69 (54.33)	1.35 (1.04, 1.75), $P = 0.027$	—	—	—
Family functioning at 14 y	—	—	—	1.67 (1.07)	1.05 (1.04)	1.66 (1.30, 2.13), P < 0.001
Maternal age at birth, y	30.42 (5.32)	27.72 (5.33)	1.06 (1.01, 1.12), $P = 0.017$	29.94 (5.60)	27.90 (5.86)	1.07 (1.02, 1.12), $P = 0.007$
Missing		55 (8.44)			96 (13.24)	

[1]Factors were identified by including the time-invariant covariates in the group-based trajectory modeling. BMI and self-reported physical activity at age 14 y and parent smoking status were also considered as covariates but were all subsequently removed during model selection.
[2]ORs of membership in group 1 of healthy dietary pattern trajectories (70% in males and 73% in females).
[3]Cells with an em-dash in this table represent variables that were not significant during the model selection.
[4]ORs of membership in group 1 of Western dietary pattern trajectories (79% in males and 81% in females).

through adolescence and into adulthood (between ages 8 and 34 y) (20). Tracking in this study was assessed using the generalized estimating equation whereby the model regressed measurements of the dietary pattern z score at follow-ups against the dietary pattern z score at baseline, adjusting for time between each measurement. The resulting β coefficients were treated as tracking coefficients as defined in Twisk et al. (46), reflecting the average change in dietary pattern score over time, based on standardized, absolute dietary intakes. It was found that for each year increase in age, the Western-like dietary pattern score increased by 0.028 z score (β: 0.028; 95% CI: 0.011, 0.045) in males, whereas no significant tracking was found for females (20). Nevertheless, this study differed by age at baseline, period of follow-up, a considerably small sample size ($n = 130$), and different statistical methods to derive dietary patterns.

In the current study, we described tracking using trajectory groups for 2 major dietary patterns. This describes the probability of trajectory group membership based on the variation in mean change measured over time. Therefore, it describes tracking at a group level and provides a visual representation of the shape of each group's trajectory. Like the Canadian study, this method also used standardized, absolute dietary intakes. Despite the methodological differences between studies, collectively, they demonstrate that unhealthy dietary patterns track between adolescence and adulthood.

Results found in the Canadian study corroborate with an increasing score for a Western dietary pattern over time in the current study, particularly among males. We have previously reported the tracking of an energy-dense, high-fat, low-fiber dietary pattern that was derived using reduced rank regression and nutrients hypothesized to contribute to obesity and cardiometabolic health in this cohort, which is similar to the Western dietary pattern. Based on Pearson correlation coefficients, z scores for this dietary pattern tracked more strongly between ages 14 and 17 y in boys ($r = 0.51$) than in girls ($r = 0.45$, $P < 0.05$), which further corroborates the findings of the current analysis (47). Other studies have examined individual food intakes between adolescence and early adulthood and observed declining intakes of whole grains, fruits, and vegetables and higher intakes of sugar-sweetened beverages and other snack foods during this period (13, 14, 48, 49).

This study indicates that family factors have potential influences on dietary pattern trajectories. For instance, males who reported consistently lower z scores for the healthy dietary pattern trajectory group were more likely to have mothers with a higher prepregnancy BMI. Maternal factors such as a higher maternal prepregnancy BMI could influence adolescents' dietary intakes through transferred behavior and attitudes, as well as through the shared home environment (e.g., less healthy food preferences) (50). On the other hand, greater maternal education was associated with a trajectory group with consistently below-average healthy pattern z scores in both males and females, which corresponds with a similar finding in children followed up between ages 7 and 13 y in a UK pregnancy cohort (40).

In the current study, having a consistently lower Western dietary pattern over time was associated with a 2-parent family structure in the majority of males. Family structure may play an important role in dietary behaviors and intake of adolescents through mechanisms such as family income and social support (51). Similarly, the likelihood of being in the dietary pattern trajectory group for declining Western pattern z scores was higher in females whose family income was higher compared with those from a family with lower income. This suggests a relation between higher food spending and healthier food purchasing in more affluent households (52).

A higher family function score in females and maternal age in both males and females were inversely related to declining scores for the Western dietary pattern in females in the current study. This is not surprising because nutrition knowledge and expertise in food preparation are likely to accumulate with age (42). Poor family function has previously been linked with obesogenic environments (53), and emerging evidence suggests a direct relation between poor family functioning and family diet quality in children (22, 54).

Our study has several strengths. The analysis of empirical dietary patterns allows an assessment of total dietary intake, rather than a focus on isolated foods or nutrients only. Our analysis identified 2 consistent dietary patterns across adolescence and into young adulthood. The timing when dietary information was collected in the Raine Study concurred with an important stage of life: adolescence through emerging adulthood. This is one of the largest studies to assess trajectories in empirical dietary patterns during this key transition period. In addition, the representation of dietary pattern scores as intercepts and slopes allowed for an exploration of changes in diet over time and identification of modifiable antecedents of these trajectories.

A limitation of our study, as with all cohort studies, is attrition, particularly of study participants from lower-income families and with lower maternal education. As such, these results may not be generalizable to all populations. All self-reported food intakes are subject to error and reporting bias. The change in the dietary assessment tool (CSIRO FFQ at ages 14 and 17 y and DQESV2 FFQ at ages 20 and 22 y) over time may have introduced some measurement error. However, despite the change in questionnaires, no major differences were observed in the dietary pattern factor loadings at each follow-up. Dietary patterns derived using a data-driven technique such as factor analysis are specific to the population under study. However, energy-dense, high-fat, low-fiber empirical dietary patterns, such as the Western dietary pattern observed in our study, have been reproduced in different cohorts and consistently associated with greater adiposity during childhood (40). Although we evaluated the contribution of some baseline childhood and parental factors to dietary pattern trajectories, these were treated as fixed variables in the analyses, but they may be subject to change. Furthermore, despite adjusting for several individual and family factors, residual confounding cannot be ruled out. Although this study benefited from a relatively large number of participants ($n = 1377$), we excluded those who did not provide dietary measurements at ≥ 2 follow-ups, and these were treated as missing at random. Last, due to the complex nature of the data set, we were not able to perform a joint dietary pattern trajectory model for assessing the possibilities of how the identified trajectories overlap. However, a simple cross-tabulation of group membership revealed that the majority of both males and females from group 1 of both the consistently declining trajectory group of the Western dietary pattern and the consistently below-average trajectory group of the healthy dietary pattern were classified similarly (**Supplemental Table 5**). This observation was similar to that found for group trajectories as presented in Figure 2.

In conclusion, poor dietary patterns (low healthy dietary pattern scores) established by adolescence were likely to track into early adulthood, and declines in diet quality during this time (increases in Western dietary pattern scores), particularly in males, were evident in this cohort. This study highlights the importance of establishing healthy dietary habits before adolescence, the significance of the transition period between adolescence and early adulthood, and the populations most likely to benefit from dietary interventions during this time.

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