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The association between dietary patterns and mental health in early adolescence

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ABSTRACT

Objective. To investigate the associations between dietary patterns and mental health in early adolescence.

Method. The Western Australian Pregnancy Cohort (Raine) Study is a prospective study of 2900 pregnancies recruited from 1989–1992. At 14 years of age (2003–2006; $n = 1324$), the Child Behaviour Checklist (CBCL) was used to assess behaviour (characterising mental health status), with higher scores representing poorer behaviour. Two dietary patterns (Western and Healthy) were identified using factor analysis and food group intakes estimated by a 212-item food frequency questionnaire. Relationships between dietary patterns, food group intakes and behaviour were examined using general linear modelling following adjustment for potential confounding factors at age 14: total energy intake, body mass index, physical activity, screen use, family structure, income and functioning, gender and maternal education at pregnancy.

Results. Higher total ($b = 2.20$, 95% CI = 1.06, 3.35), internalizing (withdrawn/depressed) ($b = 1.25$, 95% CI = 0.15, 2.35) and externalizing (delinquent/aggressive) ($b = 2.60$, 95% CI = 1.51, 3.68) CBCL scores were significantly associated with the Western dietary pattern, with increased intakes of takeaway foods, confectionary and red meat. Improved behavioural scores were significantly associated with higher intakes of leafy green vegetables and fresh fruit (components of the Healthy pattern).

Conclusion. These findings implicate a Western dietary pattern in poorer behavioural outcomes for adolescents. Better behavioural outcomes were associated with a higher intake of fresh fruit and leafy green vegetables.

Introduction

Adolescence is a crucial period of biological change and developmental potential. Current global epidemiological data estimate that one in five children is expected to develop some form of mental health problem by the time they reach adulthood, and that 50% of all adult mental health problems develop during adolescence (Belfer, 2008). According to one Australian national survey, 14% of 13 to 17 year olds had mental health problem scores in the clinical range (Sawyer et al., 2000). These and other studies have documented the association between mental health problems and suicidal ideation and other health-risk behaviour, including smoking, drinking and drug use (Patton et al., 2002). The World Health Organization (WHO) recognises mental health as a major health issue for adolescents and predicts that mental health problems will be one of the most serious global health problems by 2020 (World Health Organization 2005). Therefore investigating factors that influence mental health as expressed in behaviour and mood in young people is a high priority.

The limited literature to date suggests that poor nutrition is associated with adverse mental health, however the precise relationships between diet and mental health remain undefined (Tanskanen et al., 2001; Sublette et al., 2006). Alongside the emergence of child and adolescent mental health concerns, there have been radical changes in the diets of young people (Popkin and Gordon-Larsen, 2004) as well as global increases in the number of children and adolescents who are overweight or obese (Wang and Lobstein, 2006). National surveys in Australia indicate that between 1985 and 1995 intakes of total energy, total carbohydrates, total sugars, confectionary and soft drinks increased significantly among children aged 10 to 15 years (Cook et al., 2001). During the same period, the prevalence of overweight has doubled and obesity tripled and there have been marked increases in time spent on sedentary behaviours such as watching TV or using a computer (Booth et al., 2006) among children and adolescents. Similar findings have been observed in other Western countries (Brownson et al., 2005).

There is evidence to suggest that relationships exist between common mood or behavioural disorders and eating patterns, for example, a healthy diet has been associated with better mood and

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cognition in older adults (Samieri et al., 2008). However, very little research in adolescents has been reported and more investigations have been recommended (Bamber et al., 2007). Investigating dietary patterns has important public health implications because dietary intake is modifiable. Further, dietary pattern analysis provides an overall view of the diet that is not observed when evaluating individual nutrients alone. Given the personal, societal and economic costs of mental health and mood disorders during adolescence, the potential role of diet in moderating these conditions is an area worthy of exploration.

This study builds on the limited existing evidence regarding mental well-being and nutrition in young people. We aimed to investigate cross-sectional associations between mental health as expressed in behaviour and mood, and dietary patterns as identified in a population-based cohort of adolescents.

Methods

Study population

The Raine Study is a longitudinal pregnancy cohort study. Pregnant women ($n = 2900$) were recruited between 16 and 20 weeks gestation through the public antenatal clinic at King Edward Memorial Hospital (KEMH) and nearby private clinics in Perth, Western Australia, from May 1989 through November 1991. To be eligible for enrolment, the women were required to have sufficient English language skills, an expectation to deliver at KEMH, and an intention to reside in Western Australia to allow for future follow-up of their child (Newnham et al., 1993). A total of 2868 infants (96%) were available at birth for follow-up.

For this study we used data collected at the 14 year follow-up, at which time 1860 adolescents participated in the follow-up (357 deferred from participating, 412 had withdrawn from the study, 207 were lost to follow-up, and 32 were deceased), as this was the first year that comprehensive dietary data were collected. This research was approved by the Human Ethics Committee at KEMH and Princess Margaret Hospital for Children in Perth. Informed consent to participate in the study was obtained from the primary caregiver as well as from the adolescent.

Mental health outcomes

Indicators of adolescent mental health were measured using the Child Behaviour Checklist for Ages 4–18 (CBCL/4–18), a 118-item empirically validated measure and effective screening tool for child mental health problems that was completed by the adolescent's primary caregiver (Warnick et al., 2008). The CBCL/4–18 is a commonly used dimensional measure of child and adolescent behaviour during the previous 6 months (Achenbach, 1991). The CBCL is used to measure behaviour as a continuous score, in addition to apportioning factors into clinical syndrome scales including withdrawal, somatic complaints, anxious/depressed, social, attention, thought, aggression and delinquency scales (Achenbach, 1991). A *T*-score for overall behaviour was produced (*Mean* (M) = 46.53, *Standard Deviation* (SD) = 11.67), in addition to internalizing (withdrawal, somatic complaints, anxious/depressed) ($M = 46.62$, SD = 10.80) and externalizing (delinquency, aggression) ($M = 48.03$, SD = 11.03) behaviour sub-scales based on clinical syndromes. For the purposes of our analyses, continuous CBCL *T*-scores were used, with higher scores reflecting the presence of more behavioural problems.

Food frequency questionnaire

The adolescents' usual dietary intake over the previous 12 months was assessed with a semi-quantitative food frequency questionnaire (FFQ) developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Adelaide, Australia (Baghurst and Record, 1984). The FFQ was completed by the primary caregiver in association with the study adolescent. Respondents were asked about their usual frequency of consumption of 212 food and beverage items, excluding alcohol, and how their usual serve compared to a standard serve size given in household measurements (spoons, cups, slices, etc). All completed FFQ were checked by a research nurse and missing or unclear responses were clarified when the adolescent attended their physical assessment. The CSIRO entered and verified the FFQs and provided estimates of daily intakes of foods and nutrients using Australian food composition data. This FFQ has been shown to correctly rank a reasonable proportion of most nutrient intakes when compared to a 3-day food record in this cohort (Ambrosini et al., in press).

Table 1
Food groups included in the factor analysis (Ambrosini et al., 2009).

Food group	FFQ items
Wholegrains	Wholemeal, mixed grain or high-fibre sliced bread, oatmeal muesli, bran, wheat germ, other wholegrain breakfast cereals
Refined grains	White bread or rolls, refined breakfast cereals, crumpets, muffins, crisp bread, crackers, salted biscuits, rice, noodles, pasta
Red meats	Beef, lamb, pork, pureed meat dishes, schnitzel, offal, mince dishes hamburger patty (without bun)
Processed meat	Sausages, frankfurters, bacon, ham, fritz-devon, salami
Poultry	Roast or boiled chicken
Meat-based mixed dishes	Stew, casserole, Chinese meat and vegetables, curry, goulash
Takeaway foods	Hamburger with bun, pizza, fried chicken, sausage roll, meat pie, savoury-filled pastry
Fried fish	Fried fish, battered fish
Other fish	Steamed, grilled or canned fish, other seafood
Fried potatoes	Hot chips (french fries), potato gems (pommes noisettes)
Potato	Boiled, mashed, roasted, canned or dried potato, potato salad
Yellow or red vegetables	Carrots, pumpkin, capsicum
Other vegetables	Beetroot, zucchini, sweet corn, mushrooms, olives, celery, turnip swede, onion, cucumber, mixed vegetables
Legumes	Haricot, lima, broad or green beans, peas, baked beans, lentils
Cruciferous vegetables	Cabbage, brussels sprouts, broccoli, cauliflower, coleslaw
Leafy green vegetables	Silverbeet, lettuce
Tomato	Fresh and cooked tomato
Fresh fruit	Orange, apple, banana, fruit salad, berries, melons, peach, plum nectarine, apricot, grapes, pineapple, avocado
Canned fruit	Fruit canned in syrup or juice
Dried fruit	Sultanas, raisins, currants, other dried fruit
Cakes, biscuits, sweet pastries	Fruit loaf, sweet bun, doughnut, croissant, biscuits, cake, fruit pie or pastry, steamed pudding
Low fat dairy products	Reduced fat milk, skim milk, flavoured milk, Sustagen, low fat cheese, cottage cheese
Full fat dairy products	Whole milk, cream, ice-cream, full fat yoghurt, full fat cheese, thick shakes
Soy milk	Soy milk
Milk-based dishes	Milk pudding, mornay dishes, custard
Confectionary	Chocolate, chocolate covered bars, lollies, toffees, icy poles
Added sugar	Honey, jam, marmalade, spooned sugar
Crisps	Potato crisps, corn chips
Nuts	Peanuts, other nuts (salted and unsalted)
Sauces	Mayonnaise, salad cream, thick sauces e.g. brown sauce
Soups	Canned soup, packet soup, homemade soup
Eggs	Fried, boiled, scrambled egg, omelette
Tea, coffee	Tea, herbal tea, coffee, coffee substitute, decaffeinated coffee
Soft drinks	Coca cola, mineral water, other soft drinks, cordial fruit drink (<= 35% fruit juice)
Mineral water (plain)	Spring water
Juice	Pure fruit juice, vegetable juice
Solid spreads	Butter, butter/margarine blend, lard, table margarine
Unsaturated spreads	Canola or other monounsaturated fat margarine, polyunsaturated margarine, low fat spreads

Dietary patterns based on factor analysis have been used in several settings and have been shown to be suitable for describing usual dietary intake (Newby and Tucker, 2004). We have previously identified dietary patterns using exploratory factor analysis in this cohort at age 14 years (Ambrosini et al., 2009). Firstly, the 212 foods listed in the FFQ were collapsed into 38 food groups devised *a priori* (Table 1) and similar to those used by others (Hu et al., 2000). All 38 food groups were included in a factor analysis (maximum likelihood method) using SAS (SAS, 2002–2003). We used parameters similar to those in other studies of dietary patterns (Hu et al., 2000): only factors with an eigenvalue >1 were retained in the factor solution, the scree plot was used to confirm the number of factors to retain, and varimax rotation was applied to improve factor interpretation. Two independent factors or dietary patterns were identified which explained 50% and 34% of the total variance respectively, and we labelled these patterns 'Healthy' and 'Western' due to the foods that contributed to each pattern (Ambrosini et al., 2009). Food loadings onto each dietary pattern are shown in Table 2. Those food groups having a factor loading of 0.30 or more were regarded as important contributors to the dietary patterns. All adolescents received a score for both dietary patterns measured on the *z*-score scale, which was based on their FFQ intakes and the factor loadings for each food in Table 2.

Control variables

We adjusted for a variety of factors that could potentially confound the relationship between dietary patterns and mental health.

Total energy intake

We adjusted for total energy intake (megajoules) in the multivariable models to ensure that observed associations between dietary patterns and mental health scores were independent of the adolescents' total energy intake. This adjustment controls for extraneous variation and was conducted because most nutrient intakes in free living populations are positively correlated with total energy intake (Willett and Stampfer, 1986). Furthermore, some nutrients may be associated with disease on the basis of their correlation with energy intake (Lyons et al., 1983).

Lifestyle factors

The adolescents in the study were asked how often they exercised outside of school hours per week, where exercise was defined as activity causing breathlessness or sweating. These data were grouped based on previous studies (Ambrosini et al., 2009; O'Sullivan et al., 2009) as: *i)* exercise less than once a week, *ii)* exercise one to three times per week, and *iii)* exercise more than three times per week. Adolescents were also asked about their television or video viewing and computer use, including video games, measured as hours per day of combined screen use. We grouped these data as: *i)* less than 2 h/day, *ii)* 2 to 4 h/day, and *iii)* more than 4 h/day.

Physical measurements

A trained research assistant recorded height and weight measurements using standard calibrated equipment. Body mass index (BMI: weight (kg)/height $(m)^2$) was calculated and subjects were grouped into underweight, normal weight, overweight, and obese categories according to Cole et al. (2007, 2000) using standard criteria for this age group.

Sociodemographic and family characteristics

The primary caregiver provided information on maternal education, current family income and family structure. Maternal education, assessed as a continuous variable, represented the highest completed year of secondary education. The current annual income for the household before tax was analysed as a categorical variable and family structure was assessed as either 'yes' or 'no' for living in a single parent family. Family functioning was assessed with the General Functioning Scale from the McMaster Family Assessment Device (Epstein et al., 1983) that consisted of questions on family communication, affective responsiveness, and behaviour control. The scale has been shown to be reliable and internally consistent (Byles et al., 1988), with lower scores on the General Functioning Scale representing poorer family functioning and higher scores representing better family functioning.

Statistical analysis

Three continuous CBCL *T*-scores were examined to study the behavioural outcomes: 1) total CBCL score, 2) internalizing score and 3) externalizing score. The residuals were analysed to confirm that our model was a good fit. We then analysed the associations between continuous dietary pattern scores and each behavioural outcome using a generalized linear model. In the univariable model, the 'Western' and 'Healthy' dietary pattern scores were adjusted for each other. These analyses were then repeated with the inclusion of potential confounding variables. We tested for two-way interaction effects between our predictor variables and control variables and found no significant results, therefore we did not include interactions in the final model.

In addition, we attempted to identify key components of the dietary patterns that might explain significant associations between the dietary patterns and mental health outcomes. Intakes of food groups with a factor loading ≥0.30 on the Western or Healthy pattern (Table 2) were converted into quartiles depending on their score and entered into separate generalized linear models with potential confounding variables to test for associations with total, internalizing and externalizing CBCL scores.

Table 2
Dietary patterns and their factor loadings[a] in the Raine cohort at 14 years (Perth, Western Australia 1989–2006) (Ambrosini et al., 2009).

	Factor loadings[a]	
	'Healthy' pattern	'Western' pattern
Yellow or red vegetables	**0.56**	0.12
Leafy green vegetables	**0.49**	0.00
Tomato	**0.49**	0.00
Cruciferous vegetables	**0.48**	0.27
Other vegetables	**0.66**	0.22
Fresh fruit	**0.48**	−0.02
Legumes	**0.43**	0.19
Wholegrains	**0.39**	−0.12
Fish, steamed, grilled or tinned	**0.33**	0.05
Takeaway foods	−0.20	**0.53**
Confectionery	−0.14	**0.46**
Red meat	0.14	**0.46**
Refined grains	0.03	**0.42**
Processed meats	−0.02	**0.41**
Potato, fried e.g. french fries	−0.25	**0.39**
Crisps	−0.22	**0.39**
Soft drinks	−0.18	**0.37**
Cakes, biscuits	0.10	**0.34**
Potato, not fried	0.21	**0.34**
Sauces and dressings	0.13	**0.34**
Full fat dairy products	0.00	**0.30**
Soups	0.26	0.26
Canned fruit	0.26	0.11
Meat dishes	0.26	0.15
Dried fruit	0.23	0.00
Mineral water	0.23	−0.05
Low fat dairy products	0.22	−0.10
Eggs	0.20	0.24
Juices	0.19	−0.02
Nuts	0.17	−0.02
Added sugar	0.13	0.21
Milk dishes	0.13	0.20
Fish, fried or battered	0.02	0.23
Poultry	0.01	0.29
% Variance	50	34

[a] Foods having a factor loading of ≥30 are highlighted in bold.

All data analyses for this study were conducted with SPSS Version 15.0 (SPSS Inc., 2006).

Results

Of the 1784 primary caregivers who completed the CBCL, 1598 also provided complete dietary pattern data for analysis. The mean age of the study adolescents was 14.01 (SD ± 0.2 years), and the range was 13.0–15.0 years. Characteristics for the sample are given in Table 3.

Table 4 presents univariable and multivariable linear regression results between behaviour scores and dietary patterns. In univariable analyses, significantly lower CBCL *T*-scores for total behaviour and externalizing behaviour were associated with the Healthy dietary pattern, although this association was weakened following adjustment for total energy intake, gender, BMI category, physical activity, screen use, family structure, family income, family functioning score, and maternal education at pregnancy. In both univariable and multivariable analyses, all CBCL scores were positively associated with higher Western pattern scores. In the multivariable model, the Western dietary pattern was significantly associated with a higher total behaviour score ($b = 2.20$, 95% CI = 1.06, 3.35), internalizing score ($b = 1.25$, 95% CI = 0.15, 2.35) and externalizing score ($b = 2.60$, 95% CI = 1.51, 3.68).

Associations between total CBCL score and intakes of food groups in quartiles are presented in Table 5. Significantly lower total CBCL scores and decreasing trends in total CBCL scores were observed with increased intakes of leafy green vegetables and fresh fruit. On the other hand, higher CBCL scores were seen for adolescents in the highest intake quartiles for takeaway foods ($b = 1.89$, 95% CI = 0.07,

Table 3
Frequency data for Raine cohort at 14 years (Perth, Western Australia 1989–2006).

		Sample ($n=1598$)	
		Mean	SD
Daily energy intake (MJ)		9.6	3.0
	Missing	3	
Maternal education at birth			
	Highest school year	11.0	1.0
	Missing	4	
Family functioning score[a]		29.3	5.6
	Missing	49	
		n	%
Body mass index (BMI)	Underweight	88	5.5
	Healthy weight	960	60.1
	Overweight	256	16.0
	Obese	102	6.4
	Missing	192	12.0
Family income (AUD)	≤$25,000 pa	191	12.0
	$25,001 pa–$50,000 pa	425	26.6
	$50,001 pa–$78,000 pa	433	24.2
	>$78,000 pa	520	32.5
	Missing	29	1.8
Single parent family	Yes	313	19.6
	No	1282	80.2
	Missing	3	0.2
Gender	Male	818	51.2
	Female	779	48.7
	Missing	1	0.1
Physical activity	<1/week	125	7.8
	1–3 times/week	620	51.3
	4+ times/week	459	28.7
	Missing	194	12.1
Screen use	<2 h/day	377	23.6
	2–4 h/day	558	34.9
	4+ h/day	452	28.3
	Missing	211	13.2

[a] Assessed with General Functioning Scale from the McMaster Family Assessment Device.

3.71), red meat ($b=1.98$, 95% CI = 0.20, 3.76) and confectionary ($b=2.63$, 95% CI = 0.87, 4.39).

Although the results are not shown, we found that a high intake of fresh tomato was associated with lower internalizing behaviour scores ($b=-1.64$, 95% CI = −3.10, −0.18) and lower externalizing scores ($b=-2.13$, 95% CI = −3.75, −0.51). Further, lower externalizing scores were linked to the highest quartile of intake for leafy green vegetables ($b=-2.05$, 95% CI = −3.76, −0.34). The highest quartile for confectionary intake was associated with higher scores for internalizing ($b=1.91$, 95% CI = 0.22, 3.59) and externalizing behaviour ($b=2.53$, 95% CI = 0.86, 4.20). Takeaway foods ($b=2.47$, 95% CI = 0.74, 4.20), red meat ($b=1.88$, 95% CI = 0.19, 3.58) and potato crisps ($b=1.85$, 95% CI = 0.16, 3.54) were also associated with higher externalizing scores.

Discussion

Our results show that higher CBCL scores, representing poorer mental health in early adolescence, were associated with an increased intake of the Western dietary pattern, particularly takeaway foods, red meat and confectionary (components of this pattern). We found that improved behavioural scores were associated with higher intakes of leafy green vegetables and fruit but not with an overall Healthy dietary pattern.

The size of the regression coefficients linking the Western dietary pattern and CBCL *T*-scores (Table 4) was larger in the adjusted model for externalizing behaviour (delinquent and/or aggressive behaviour) in comparison with internalizing behaviour (withdrawal, somatic complaints, anxious/depressed behaviour). These findings suggest that the associations observed in this study may manifest more in the behaviour of the child in relation to others, rather than as symptoms of inner distress (Achenbach and McConaughy, 1997) and provide support for existing research linking a poor quality diet to externalizing behaviour (Liu et al., 2004). Items that make up the externalizing score include bragging, lying, running away, stealing, truancy, arguing, fighting, disobedience, sudden mood changes, and temper tantrums, and are often termed 'conduct problems' (Achenbach and McConaughy, 1997).

Within the Western dietary pattern, three key food groups; takeaway foods, red meat and confectionary, were associated with a higher total CBCL score. Confectionary products are generally high in refined sugar, energy dense and low in essential micronutrients, and are often eaten in the place of more nutrient-dense foods (National Health and Medical Research Council, 2003). It has been estimated that a quarter of adolescents' daily energy intake is in the form of snacks (Summerbell et al., 1995), which suggests that confectionary may be replacing more nutritious foods. Red meat is an important provider of the essential nutrients for brain functioning including iron, zinc, vitamin B12 and niacin (Bodnar and Wisner, 2005). However, red meats, along with takeaway foods, tend to be sources of saturated fat, which can contribute to insulin sensitivity and metabolic syndrome (Riserus, 2008). The associations of fruits and leafy green vegetables with lower behaviour scores in our study may be due to their micronutrient content, in particular folate required for neurotransmitters (Bodnar and Wisner, 2005) and antioxidants (e.g. vitamin C, carotenoids and vitamin E) for preventing inflammation, which has been associated with depressive states (Ford and Erlinger, 2004) and is closely linked with metabolic syndrome (Giugliano et al., 2006). The result observed for fresh tomato and internalizing and externalizing behaviour observed could be explained by the high lycopene content of tomato. Lycopene gives tomatoes a strong antioxidant activity and assists in decreasing oxidative stress and free radical cell damage (Frusciante et al., 2007). Major depressive disorder has been associated with oxidative stress (Sarandol et al., 2007), and a positive relationship has been reported between the potency of oxidative stress and severity of depression (Yanik et al., 2004). Finally, there is a growing body of research examining essential fatty acids and mental health that suggests a diet high in essential fatty acids is associated with better mood and cognition (Hallahan and Garland, 2005).

Study limitations and strengths

To our knowledge this is the first population-based study to examine mental health as assessed by behavioural scores and dietary

Table 4
Univariable and multivariable linear regression coefficients for Child Behaviour Checklist *T*-scores at 14 years for Healthy and Western dietary patterns in the Raine cohort (Perth, Western Australia 1989–2006) [$n=1324$].

	CBCL total	CBCL internalizing	CBCL externalizing
Score for Healthy dietary pattern			
Unadjusted beta coefficient[a]	−1.06	−0.57	−0.97
(95% CI)	(−1.68, −0.44)	(−1.16, 0.02)	(−1.55, −0.38)
p-value	0.001	0.057	0.001
Adjusted beta coefficient[c]	−0.24	0.17	−0.29
(95% CI)	(−0.97, 0.50)	(−0.54, 0.88)	(−0.98, 0.42)
p-value	0.528	0.642	0.419
Score for Western dietary pattern			
Unadjusted beta coefficient[b]	2.69	1.27	2.95
(95% CI)	(2.05, 3.33)	(0.67, 1.87)	(2.35, 3.55)
p-value	<0.001	<0.001	<0.001
Adjusted beta coefficient[c]	2.20	1.25	2.60
(95% CI)	(1.06, 3.35)	(0.15, 2.35)	(1.51, 3.68)
p-value	<0.001	0.026	<0.001

[a] Adjusted for Western pattern score.
[b] Adjusted for Healthy pattern score.
[c] Analysis adjusted for: total energy intake, BMI category, physical activity, screen use, family structure, family income, family functioning and gender at age 14 and maternal education at pregnancy.

Table 5
Multivariable general linear model analyses: Child Behaviour Checklist *T*-scores for total behaviour at 14 years and individual food groups in the Raine cohort (Perth, Western Australia 1989–2006).

		Quartiles of intake ($n=1324$)				*p* for trend[a]
		1	2	3	4	
Healthy pattern						
Yellow/red vegetables	*b*	1.00	−0.09	−0.65	−0.51	0.46
	(95% CI)		(−1.79, 1.61)	(−2.35, 1.05)	(−2.24, 1.23)	
Leafy green vegetables	*b*	1.00	−0.35	**−2.28***	**−1.98***	**0.01***
	(95% CI)		(−2.14, 1.44)	(−4.08, −0.48)	(−3.80, −0.16)	
Tomato	*b*	1.00	0.98	−1.18	−0.90	0.09
	(95% CI)		(−0.73, 2.68)	(−2.71, 0.34)	(−2.53, 0.73)	
Cruciferous vegetables	*b*	1.00	0.00	0.48	0.77	0.31
	(95% CI)		(−1.65, 1.65)	(−1.16, 2.12)	(−0.92, 2.46)	
Other vegetables	*b*	1.00	−0.48	−0.34	−0.19	0.87
	(95% CI)		(−2.12, 1.17)	(−2.00, 1.33)	(−1.90, 1.52)	
Fresh fruit	*b*	1.00	−0.37	−0.61	**−2.16***	**0.02***
	(95% CI)		(−2.00, 1.27)	(−2.31, 1.09)	(−3.92, −0.41)	
Legumes	*b*	1.00	0.23	0.59	1.27	0.13
	(95% CI)		(−1.42, 1.87)	(−1.07, 2.24)	(−0.40, 2.95)	
Wholegrains	*b*	1.00	−0.03	−0.26	−1.06	0.22
	(95% CI)		(−1.69, 1.64)	(−1.91, 1.40)	(−2.77, 0.65)	
Fish, steamed, grilled or tinned	*b*	1.00	−0.80	−0.27	−1.32	0.18
	(95% CI)		(−2.51, 0.91)	(−1.84, 1.30)	(−2.94, 0.29)	
Western pattern						
Takeaway foods	*b*	1.00	0.28	0.21	**1.89***	0.07
	(95% CI)		(−1.38, 1.95)	(−1.49, 1.90)	(0.07, 3.71)	
Confectionary	*b*	1.00	**1.71***	1.52	**2.63****	**0.01***
	(95% CI)		(0.07, 3.34)	(−0.12, 3.16)	(0.87, 4.39)	
Red meat	*b*	1.00	1.33	1.08	**1.98***	**0.05***
	(95% CI)		(−0.31, 2.96)	(−0.62, 2.77)	(0.20, 3.76)	
Refined grains	*b*	1.00	0.70	0.24	−0.14	0.77
	(95% CI)		(−0.97, 2.37)	(−1.44, 1.91)	(−1.98, 1.70)	
Processed meat	*b*	1.00	−0.73	−0.86	0.05	0.99
	(95% CI)		(−2.39, 0.92)	(−2.57, 0.84)	(−1.72, 1.82)	
Potato, fried	*b*	1.00	0.47	1.14	1.39	0.12
	(95% CI)		(−1.48, 2.43)	(−1.48, 3.77)	(−0.43, 3.22)	
Crisps	*b*	1.00	1.07	1.08	0.76	0.33
	(95% CI)		(−1.62, 3.75)	(−0.88, 3.05)	(−1.04, 2.56)	
Soft drinks	*b*	1.00	**1.93***	1.45	0.52	0.63
	(95% CI)		(0.29, 3.57)	(−0.20, 3.10)	(−1.23, 2.28)	
Cakes, biscuits	*b*	1.00	−1.16	−1.48	−1.11	0.74
	(95% CI)		(−2.83, 0.51)	(−3.21, 0.25)	(−2.97, 0.76)	
Potato not fried	*b*	1.00	0.54	1.08	0.51	0.44
	(95% CI)		(−1.10, 2.18)	(−0.59, 2.75)	(−1.22, 2.24)	
Sauces and dressings	*b*	1.00	0.56	0.29	1.07	0.29
	(95% CI)		(−1.19, 2.32)	(−1.46, 2.05)	(−0.67, 2.80)	
Full fat dairy products	*b*	1.00	−0.04	−0.15	−0.25	0.76
	(95% CI)		(−1.71, 1.63)	(−1.85, 1.56)	(−2.09, 1.61)	

*$p<0.05$, **$p<0.005$, reference category is the first quartile of intake. Each analysis for each specific food adjusted for: total energy intake, BMI category, physical activity, screen use, family structure, family income, family functioning and gender at age 14 and maternal education at pregnancy.

[a] Obtained by analysing quartiles of food intake as continuous variable.

patterns in an adolescent population, although a recent study has examined younger children (Wiles et al., 2007). Our study has a number of strengths. Importantly, we were able to control for a variety of potential confounders, including psychosocial and demographic factors, physical activity and sedentary behaviour (television viewing and computer use). We used a valid and reliable measure of adolescent behaviour (Warnick et al., 2008) and the large sample size allowed for good response fractions. By analysing dietary patterns the effect of the whole diet was considered (Hu, 2002). While there are other empirical methods available for identifying major dietary patterns, for example cluster analysis, we used factor analysis because this method is more commonly used in the nutritional epidemiology literature (Newby and Tucker, 2004) and has been shown to be a reliable method for identifying dietary patterns (Khani et al., 2004). The FFQ was completed by the primary caregiver in association with the adolescent to reduce calculation error because it may be difficult for young adolescents to estimate out how often food is consumed and in what portion size (Margetts and Nelson, 1997). However, the cross-sectional design of this study does not allow causal relationships to be established. Although the relationships persisted after adjustment for familial factors and socio-economic status these potentially did not fully account for social factors influencing eating patterns. Dietary patterns may be influenced by mood or emotional distress, which can induce a preference for sweet carbohydrate (confectionary) or fat-rich snack foods in order to enhance mood (Christenson, 1997). Finally it is possible that, due to the many statistical tests conducted, some of the significant findings for the food groups may be due to chance.

Conclusion

In summary, we have shown in a population cohort of adolescents that behavioural scores were correlated with dietary patterns. Our study suggests that poorer behaviour in early adolescence, after adjustment for socio-economic and lifestyle factors, was associated with a Western dietary pattern (a diet high in red and processed meats, takeaway foods, confectionary and refined foods). The results of our study have important implications for public health policy-

makers, given that diet is a modifiable risk factor. To date this is one of the few studies to report on the associations between mental health and dietary patterns in an adolescent population and therefore further studies are required to support our findings.

Conflict of interest statement
The authors declare that there are no financial interests or conflicts of interest to disclose.

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References

Achenbach, T.M., 1991. Manual for the Child Behavior Checklist/4–18 and 1991 Profile. University of Vermont, Department of Psychiatry, Burlington.
Achenbach, T.M., McConaughy, S.H., 1997. Empirically Based Assessment of Child and Adolescent Psychopathology2nd ed. Sage Publications, Thousand Oaks.
Ambrosini, G. L., Oddy, W. H., Robinson, M., et al., 2009, 'Adolescent dietary patterns and their lifestyle and socio-demographic correlates', Public Health Nutrition. Available from: http://journals.cambridge.org/action/displayAbstract?aid=3485956, vol. epub ahead of print published 23 January, 2009.
Ambrosini, G.L., de Klerk, N.H., O'Sullivan, T.A., Beilin, L.J., Oddy, W.H., in press. The reliability of a food frequency questionnaire for use among adolescents. Eur. J. Clin. Nutr. (Accepted 16th May 2009).
Baghurst, K.I., Record, S.J., 1984. A computerised dietary analysis system for use with diet diaries or food frequency questionnaires. Community Health Stud. 8 (1), 11–18.
Bamber, D.J., Stokes, C.S., Stephen, A.M., 2007. The role of diet in the prevention and management of adolescent depression. Nutr. Bull. 32 (s1), 90–99.
Belfer, M.L., 2008. Child and adolescent mental disorders: the magnitude of the problem across the globe. J. Child Psychol. Psychiatry Allied Discipl. 49 (3), 226–236.
Bodnar, L.M., Wisner, K.L., 2005. Nutrition and depression: implications for improving mental health among childbearing-aged women. Biol. Psychiatry 58 (9), 679–685.
Booth, M., Okely, A.D., Denney-Wilson, E., Hardy, L., Yang, B., Dobbins, T., 2006. NSW Schools Physical Activity and Nutrition Survey (SPANS) 2004: Summary Report. NSW Department of Health, Sydney.
Brownson, R.C., Boehmer, T.K., Luke, D.A., 2005. Declining rates of physical activity in the United States: what are the contributors? Annu. Rev. Public Health 26, 421–443.
Byles, J., Byrne, C., Boyle, M.H., Offord, D.R., 1988. Ontario Child Health Study: reliability and validity of the General Functioning Subscale of the McMaster Family Assessment Device. Fam. Proc. 27 (1), 97–104.
Christenson, L., 1997. The effect of carbohydrates on affect. Nutrition 13 (6), 503–514.
Cole, T.J., Bellizzi, M.C., Flegal, K.M., Dietz, W.H., 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. Br. Med. J. 320 (7244), 1240–1243.
Cole, T.J., Flegal, K.M., Nicholls, D., Jackson, A.A., 2007. Body mass index cut offs to define thinness in children and adolescents: international survey. Br. Med. J. 335 (7612), 194–202.
Cook, T., Rutishauser, I., Seelig, M., 2001. Comparable Data on Food and Nutrient Intake and Physical Measurements from 1983, 1985 and 1995 Surveys., Australian Food and Nutrition Monitoring and Surveillance Unit. University of Queensland and Commonwealth Department of Health and Aged Care, Canberra.
Epstein, N.B., Baldwin, L.M., Bishop, D.S., 1983. The McMaster Family Assessment Device. J. Marital Fam. Ther. 9 (2), 171–180.
Ford, D.E., Erlinger, T.P., 2004. Depression and C-reactive protein in US adults: data from the Third National Health and Nutrition Examination Survey. Arch. Intern. Med. 164 (9), 1010–1014.
Frusciante, L., Carli, P., Ercolano, M.R., et al., 2007. Antioxidant nutritional quality of tomato. Mol. Nutr. Food Res. 51 (5), 609–617.
Giugliano, D., Ceriello, A., Esposito, K., 2006. The effects of diet on inflammation: emphasis on the metabolic syndrome. J. Am. Coll. Cardiol. 48 (4), 677–685.
Hallahan, B., Garland, M., 2005. Essential fatty acids and mental health. Br. J. Psychiatry 186 (4), 275–277.
Hu, F.B., 2002. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr. Opin. Lipid. 13, 3–9.
Hu, F.B., Rimm, E.B., Stampfer, M.J., Ascherio, A., Spiegelman, D., Willett, W.C., 2000. Prospective study of major dietary patterns and risk of coronary heart disease in men. Am. J. Clin. Nutr. 72 (4), 912–921.
Khani, B.R., Ye, W., Terry, P., Wolk, A., 2004. Reproducibility and validity of major dietary patterns among Swedish women assessed with a food-frequency questionnaire. J. Nutr. 134 (6), 1541–1545.
Liu, J., Raine, A., Venables, P.H., Mednick, S.A., 2004. Malnutrition at age 3 years and externalizing behavior problems at ages 8, 11, and 17 years. Am. J. Psychiatry 161 (11), 2005–2013.
Lyons, J., Gardener, J., West, D., 1983. Methodologic issues in epidemiologic studies of diet and cancer. Cancer Res. 43, S2392–S2396.
Margetts, B., Nelson, M., 1997. Design Concepts in Nutritional Epidemiology2nd edn. Oxford University Press, Oxford.
National Health and Medical Research Council, 2003. Dietary Guidelines for Children and Adolescents in Australia. Commonwealth of Australia, Canberra.
Newby, P.K., Tucker, K.L., 2004. Empirically derived eating patterns using factor or cluster analysis: a review. Nutr. Rev. 62 (5), 177–203.
Newnham, J.P., Evans, S.F., Michael, C.A., Stanley, F.J., Landau, L.I., 1993. Effects of frequent ultrasound during pregnancy: a randomised controlled trial. Lancet 342, 887–891.
O'Sullivan, T.A., Robinson, M., Kendall, G.E., et al., 2009. A good quality breakfast is associated with better mental health in adolescence. Public Health Nutr. 12 (2), 249–258.
Patton, G.C., Coffey, C., Carlin, J.B., Degenhardt, L., Lynskey, M., Hall, W., 2002. *Cannabis* use and mental health in younger people: cohort study. Br. Med. J. 325 (7374), 1195–1198.
Popkin, B.M., Gordon-Larsen, P., 2004. The nutrition transition: worldwide obesity dynamics and their determinants. Int. J. Obes. 28 (3).
Riserus, U., 2008. Fatty acids and insulin sensitivity. Curr. Opin. Clin. Nutr. Metab. Care 11 (2), 100–105.
Samieri, C., Jutand, M.A., Feart, C., Capuron, L., Letenneur, L., Barberger-Gateau, P., 2008. Dietary patterns derived by hybrid clustering method in older people: association with cognition, mood, and self-rated health. J. Am. Diet. Assoc. 108 (9), 1461–1471.
Sarandol, A., Sarandol, E., Eker, S.S., Erdinc, S., Vatansever, E., Kirli, S., 2007. Major depressive disorder is accompanied with oxidative stress: short-term antidepressant treatment does not alter oxidative–antioxidative systems. Hum. Psychopharmacol. 22 (2), 67–73.
SAS, 2002–2003. SAS for Windows, ed.^eds 9.1.3. SAS Institute Incorporated, Cary, NC, USA.
Sawyer, M.G., Kosky, R.J., Graetz, B.W., Arney, F., Zubrick, S.R., Baghurst, P., 2000. The National Survey of Mental Health and Wellbeing: the child and adolescent component. Aust. N. Z. J. Psychiatry 34 (2), 214–220.
SPSS Inc. 2006, SPSS 15.0 for Windows, Chicago.
Sublette, M.E., Hibbeln, J.R., Galfalvy, H., Oquendo, M.A., Mann, J.J., 2006. Omega-3 polyunsaturated essential fatty acid status as a predictor of future suicide risk. Am. J. Psychiatry 163 (6), 1100–1102.
Summerbell, C.D., Moody, R.C., Shanks, J., Stock, M.J., Geissler, C., 1995. Sources of energy from meals versus snacks in 220 people in four age groups. Eur. J. Clin. Nutr. 49 (1), 33–41.
Tanskanen, A., Hibbeln, J.R., Tuomilehto, J., et al., 2001. Fish consumption and depressive symptoms in the general population in Finland. Psychiatr. Serv. 52 (4), 529–531.
Wang, Y., Lobstein, T., 2006. Worldwide trends in childhood overweight and obesity. Int. J. Pediatr. Obes. 1 (1), 11–25.
Warnick, E.M., Bracken, M.B., Kasl, S., 2008. Screening efficiency of the Child Behavior Checklist And Strengths And Difficulties Questionnaire: a systematic review. Child Adolesc. Ment. Health 13 (3), 140–147.
Wiles, N.J., Northstone, K., Emmett, P., Lewis, G., 2007. 'Junk food' diet and childhood behavioural problems: results from the ALSPAC cohort. Eur. J. Clin. Nutr. 1–8 vol. advance online publication.
Willett, W., Stampfer, M.J., 1986. Total energy-intake — implications for epidemiologic analyses. Am. J. Epidemiol. 124 (1), 17–27.
World Health Organization, 2005. Atlas: Child and Adolescent Mental Health Resources. World Health Organization, Geneva.
Yanik, M., Erel, O., Kati, M., 2004. The relationship between potency of oxidative stress and severity of depression. Acta Neuropsychiatr. 16 (4), 200–203.