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# Does an inflammatory diet affect mental well-being in late childhood and mid-life? A cross-sectional study

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## Abstract

Inflammatory diets are increasingly recognised as a modifiable determinant of mental illness. However, there is a dearth of studies in early life and across the full mental well-being spectrum (mental illness to positive well-being) at the population level. This is a critical gap given that inflammatory diet patterns and mental well-being trajectories typically establish by adolescence. We examined the associations of inflammatory diet scores with mental well-being in 11–12-year-olds and mid-life adults. Throughout Australia, 1759 11–12-year-olds (49 % girls) and 1812 parents (88 % mothers) contributed cross-sectional population-based data. Alternate inflammatory diet scores were calculated from a twenty-six-item FFQ, based on the prior literature and prediction of inflammatory markers. Participants reported negatively and positively framed mental well-being via psychosocial health, quality of life and life satisfaction surveys. We used causal inference modelling techniques via generalised linear regression models (mean differences and risk ratios (RR)) to examine how inflammatory diets might influence mental well-being. In children and adults, respectively, a 1 SD higher literature-derived inflammatory diet score conferred between a 44 % (RR 95 % CI 1·2, 1·8) to 57 % (RR 95 % CI 1·3, 2·0) and 54 % (95 % CI 1·2, 2·0) to 86 % (RR 95 % CI 1·4, 2·4) higher risk of being in the worst mental well-being category (i.e. <16th percentile) across outcome measures. Results for inflammation-derived scores were similar. BMI mediated effects (21–39 %) in adults. Inflammatory diet patterns were cross-sectionally associated with mental well-being at age 11–12 years, with similar effects observed in mid-adulthood. Reducing inflammatory dietary components in childhood could improve population-level mental well-being across the life course.

**Key words:** **Inflammatory diet: Mental health: Prevention: Children**

Diet is increasingly recognised as a modifiable factor for mental health, with inflammatory pathways a key suggested underlying mechanism[1]. Randomised controlled trials in adults support this hypothesis, with anti-inflammatory dietary intervention (i.e. high in fruit, vegetables, low-fat dairy products, fish and wholegrains, and moderate in unsaturated fat) shown to decrease symptoms of depression[2]. Similarly, longitudinal studies in adults and adolescents suggest that pro-inflammatory diets (i.e. high in sugar, saturated fats, refined carbohydrates and red meat) increase the risk of mental illness[1]. In reality, an individual's habitual diet is rarely anti- or pro-inflammatory but is a composite of both. This overall inflammatory potential of diet has also been shown to affect mental illnesses, such as major depression and schizophrenia[1,3]. However, it is unclear whether an individual's overall dietary inflammatory potential affects the full mental well-being spectrum (i.e. from diagnosed mental illness to general well-being/happiness) at the population level and, if so, when in the life course effects begin to emerge.

The Dietary Inflammatory Index (DII) is the only standardised dietary score of overall inflammatory potential[4]. It assigns

**Abbreviations:** CheckPoint, Child Health CheckPoint; DII, Dietary Inflammatory Index; GlycA, glycoprotein acetyls; LSAC, Longitudinal Study of Australian Children; NaSSDA, National Secondary Students' Diet and Activity; QoL, quality of life; SEP, socio-economic position.

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specific values to both pro- and anti-inflammatory foods using FFQ with a minimum of forty-five items, derived from the literature and validated against inflammatory biomarkers (e.g. C-reactive protein)[4]. In a recent systematic review, eleven out of twelve studies showed that a higher DII (i.e. more inflammatory potential) was associated with a higher risk of depression in adults[3]. These findings were recently extended beyond depression in a large sample of mid-life Irish adults (51 % female; 50–69 years) to anxiety symptoms and positive well-being (i.e. validated, survey-assessed, positively framed items such as 'I have felt cheerful and in good spirits')[5]. Women with a higher DII score (tertile 1 *v.* 3) had at least doubled odds of experiencing elevated depression and anxiety symptoms, and a lower likelihood of reporting positive well-being; however, there was little evidence of associations in men.

Fewer studies looking at inflammatory diet and mental health have been conducted in children and adolescents. In a study of adolescent Iranian girls, those with high DII scores (tertile 1 *v.* 3) were at least three times more likely to have moderate stress scores[6]. Similarly, in an Australian cohort, a pro-inflammatory 'Western' dietary pattern at 14 years of age was indirectly associated with mental health problems 3 years later, with effects mediated via adiposity and inflammatory pathways[7]. In addition, in Spanish children and adolescents, adhering to an anti-inflammatory Mediterranean diet was cross-sectionally associated with higher levels of well-being (health-related quality of life and positive and negative effects), but not associated with well-being 2 years later[8].

These recent studies suggest that the inflammatory potential of diet may affect mental well-being from childhood onwards, but the scarcity of studies in younger children and the lack of positive well-being measures warrant further investigation. Such knowledge would inform public health campaigns to target the most appropriate age group/s and also elucidate the aetiology of mental well-being. This is particularly important in childhood when dietary patterns become established[9] and given that over half of lifetime mental health disorders develop by early adolescence[10]. In addition, more recently described inflammatory markers (e.g. glycoprotein acetyls (GlycA)) may better reflect cumulative inflammation and more diverse inflammatory pathways than acute phase reactants such as C-reactive protein[11] and therefore may be more informative regarding diet-related inflammation.

Thus, we used causal modelling techniques[12] to account for underlying confounding structures to best examine potential pathways between inflammatory diet scores and mental well-being in two generations (11–12-year-olds and mid-life adults) in a population-based study. We used both a literature- and GlycA-derived inflammatory diet score.

## Methods

### Study design

The Child Health CheckPoint (CheckPoint) was a physical/biomarkers module nested within the population-based Longitudinal Study of Australian Children (LSAC)[13]. The cross-sectional CheckPoint data were collected across Australia in 2015–2016 between LSAC's 6th and 7th waves, when children were aged 11–12 years. The Royal Children's Hospital (HREC33225) and The Australian Institute of Family Studies (AIFS4-05) Ethics Committees approved the project. Written informed consent from a parent/guardian was provided for their child, as well as their own participation.

### Participants

Details of the CheckPoint methods are described elsewhere[13] and are summarised below. In 2004, LSAC randomly recruited a nationally representative sample of 5107 infants (age 0–1 years) into its Birth (B) cohort. LSAC has since followed these families biennially, with six waves of data collection complete in 2014 (retention rate 75 %). The CheckPoint was offered to all B-cohort families that took part in wave 6 (Appendix Figure 1).

### Procedure

Most participants attended a 3·5-h main or 2·5-h Mini Assessment Center in one of Australia's capital cities or large regional towns. Participants rotated through a series of 15-min physical assessment and biospecimen collection stations at which semi-fasting venous blood samples were collected, as detailed elsewhere[14]. Serum aliquots were frozen at −80°C and then shipped to Finland for metabolomics analysis via a high-throughput proton NMR metabolomics platform (Nightingale Health), generating the inflammatory biomarker GlycA. Participants unable to attend the Center were offered a 90-min home visit. On an iPad, parents and children separately self-reported standardised survey measures regarding their diet and mental well-being at all three types of assessments, but those having home visits did not contribute venous blood.

### Measures

Despite the cross-sectional nature of the study, we considered the exposure variables to be the inflammatory diet scores and the outcome variables to be the mental well-being measures.

*Inflammatory diet scores.* On an iPad, children and adults separately self-reported their usual intake of various foods and drinks via the National Secondary Students' Diet and Activity (NaSSDA) survey[15]. The twenty-six-item survey fell short of the minimum forty-five items needed to calculate the DII[4]. Therefore, we used each relevant NaSSDA item (twenty-three of the twenty-six items) to derive two inflammatory diet scores based on: (1) published literature ('literature-derived') and (2) the statistical correlations with levels of GlycA ('GlycA-derived'). Procedures used to calculate inflammatory diet scores can be found elsewhere[16] and are summarised below. Higher scores indicate a more pro-inflammatory diet. NaSSDA items allow direct comparison with the Australian Dietary Guidelines and demonstrate good validity[15] and expected gradients with socio-economic position[17]. Appendix Table 1 details the scoring for each NaSSDA item for both inflammatory diet scores.

The literature-derived inflammatory diet score was generated using two highly cited reviews[14,18] that used C-reactive protein to establish the 'inflammatory potential' of commonly consumed different food and beverage components. Based on this information, we classified each NaSSDA item as either anti-inflammatory

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(e.g. fish consumption) or pro-inflammatory (e.g. red meat consumption). We then assigned each item's response options a value from −2 (anti-inflammatory) to +2 (pro-inflammatory) and summed all items to calculate an overall literature-derived inflammatory diet score for each participant.

The GlycA-derived inflammatory diet score was based on parents' measured inflammatory GlycA, because GlycA as a marker of chronic inflammation at the time the score was derived was based on adult populations[11]; we then applied this score to the child NaSSDA data. GlycA values were highly positively skewed; therefore, we naturally log-transformed the values. Following this, adult NaSSDA items were individually regressed against log-transformed GlycA values (univariable models) and items that reached a statistical significance level of $P < 0{\cdot}20$ and were entered into Multivariable Model 1 to ascertain their combined association with GlycA. Items that remained associated in Model 1 were then entered into a final Multivariable Model 2 (Appendix Table 1). The coefficients from this final model were then used to generate an inflammatory diet score for each adult and child with the following formula:

*'sum(model regression coefficient for item multiplied by participants' NaSSDA item response value) + 'model constant'*.

*Mental well-being measures.* Table 1 details each mental well-being measure. All cumulative scores are on a 0–1 or 0–100 scale; higher scores indicate better mental well-being.

For children, measures tapping into mental well-being included two negatively framed measures: overall health-related quality of life (QoL) assessed via the child version of the Child Health Utility-9D[19]; and Psychosocial QoL assessed via the psychosocial summary score of the Pediatric QoL Inventory[20]. We also included two positively framed measures: General well-being, assessed via General Wellbeing Scale[20]; and Life satisfaction, assessed via the International Scale of Child Wellbeing's Brief Multidimensional Students' Life Satisfaction sub-scale[21].

For adults, the mental well-being measures included Psychosocial QoL assessed via the psychosocial health domain of the Assessment of Quality of Life 8D (AQoL-8D-PS)[22]; and health-related QoL assessed via the adult version of the Child Health Utility-9D[19].

*Potential confounders.* Potential confounders included age, sex and a range of measures to tap into the socio-economic background (socio-economic position (SEP), neighbourhood disadvantage and education level), given that lower socio-economic background is associated with unhealthier diets[23] and worse mental health[24]. SEP was calculated from the most recently available parent-reported education, income and occupation data at LSAC's wave 6. Scores were internally standardised (mean: 0; standard deviation (SD): 1), where higher scores represent higher SEP[25]. Neighbourhood disadvantage was calculated based on family postcode of residence at the

**Table 1.** Mental well-being measures

| Measure | Instrument | Additional information |
|---|---|---|
| Child life satisfaction (5 items) | International Survey of Children's Wellbeing (ISCW) Brief Multidimensional Students' Life Satisfaction sub-scale[21] | Questions are framed from a positive perspective over life as a whole (no specific recall time), and assess 5 life domains: family, friends, school, local area and body. Each item is scored on an 11-point Likert scale. The total summed life satisfaction score is linearly transformed to a 0 to 100 scale, with higher scores indicating better life satisfaction[21]. It has good internal consistency reliability ($\alpha = 0{\cdot}75$)[36]. |
| Child general well-being (7 items) | Pediatric Quality of Life (PedsQL) 4.0 General Wellbeing sub-scale[20] | Questions are framed from a positive perspective over a recall time of 1 month, and assess happiness, perceived support and optimism about the future. Each item is scored on a 5-point Likert scale. The total summed score is linearly transformed to a 0 to 100 scale, where higher scores indicate better general well-being[20]. It has good internal consistency reliability ($\alpha = 0{\cdot}70$–$0{\cdot}92$)[20]. |
| Child psychosocial health (15 items) | Paediatric Quality of Life (PedsQL) 4.0 Psychosocial Health sub-scale[20] | Questions are framed from a negative perspective over a 1-month recall time and assess emotional, social and school functioning. Items are reverse-scored on a 5-point Likert scale. The total summed score is linearly transformed to a 0 to 100 scale, where higher scores indicate better psychosocial health[20].The Psychosocial Health Summary Score has good internal consistency reliability ($\alpha = 0{\cdot}83$ child, 0·86 adults)[37]. |
| Child and adult health-related quality of life (9 items) | Child Health Utility 9D (CHU9D)[38] | Questions are framed from a negative perspective, assessing functioning "today" across the domains of sadness, worry, tiredness, pain, annoyance, daily routine, sleep and activities. Each item is scored on a 5-point Likert scale, with each domain being weighted according to the utility values determined for Australian children. Scores represent a weighted sum on a 0–1 scale, with higher scores indicating better health-related quality of life. The wording of questions was modified for use in adults[38]. It has good internal consistency reliability ($\alpha = 0{\cdot}78$)[38]. |
| Adult psychosocial quality of life (25 items) | Assessment of quality of life 8D (AQoL8D) Psychosocial Health sub-scale[22] | Questions are framed from a negative, positive or neutral perspective and assess functioning over the past month across the domains of relationships, mental health, coping, happiness and self-worth. Each item is scored on a 4- to 6-point Likert scale. Scores represent a weighted sum on a 0–1 scale, where higher scores indicate better psychosocial quality of life[22]. It has good internal consistency reliability ($\alpha = 0{\cdot}96$)[39]. |

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CheckPoint using the census-derived Index of Relative Socio-economic Disadvantage (SEIFA; national mean: 1000; SD: 100, where higher values = less disadvantage)[26]. Using all three socio-economic variables was deemed appropriate as they were not highly correlated (<0·30).

*Potential mediator.* Given that an inflammatory diet is directly implicated in higher BMI, and that BMI is known to influence mental well-being[1] particularly in adults, we considered whether BMI was a mediator of the effect of a pro-inflammatory diet on mental well-being. Child and adult BMI (kg/m2) was calculated from researcher-measured height and weight. For children, BMI was converted to age- and sex-specific BMI *z*-scores (CDC reference values)[27].

### Statistical analyses

Each of the inflammatory diet scores was dichotomised as above the 75th percentile compared with the rest. We dichotomised the dietary exposure given that it was unlikely that the continuous version would meet the assumption of linearity (i.e. that a one-unit change is the same at all levels of this exposure). Each mental well-being score was considered continuously and dichotomously (<1 SD below the mean (i.e. <16th percentile)) to identify those at the highest risk of poor mental well-being. Child and adult analyses were considered separately.

To examine whether a diet high in pro-inflammatory potential affects mental well-being, we used two causal modelling approaches to account for underlying confounding structures in order to estimate the same causal effects: First, a classical regression approach which makes an assumption about constant effects within confounder strata and second, a more flexible approach that does not require those assumptions, which is implemented by extending those regressions to include interactions between the exposure and confounders (SEP and SEIFA in this instance), and then averaging the causal effects within strata using the margins command.

We used ordinary linear regression to estimate mean difference and log-binomial regression to estimate risk ratios in models adjusted for age, sex, SEP, SEIFA and education (parent education for children). A mediation analysis was also used to examine BMI as a mediator of the association between a pro-inflammatory diet and mental well-being. The mediation analysis estimated the total causal effect of inflammatory diet ('exposure') on mental well-being ('outcome') occurring via an intermediate variable ('mediator'; BMI in this case) using the 'paramed command'. All analyses were conducted in 2020 using Stata/IC(15.1).

## Results

### Sample characteristics

Of the 3513 families retained at LSAC's wave 6, 1874 (50 %) parent–child dyads took part in the CheckPoint (see Appendix Figure 1). The analytic sample included 1812 adults (mean age 43·7 years (SD 5·2)) and 1759 11–12-year-olds who had at least one inflammatory diet score and one mental well-being measure.

Sex was evenly distributed in children (49 % girls), but adults were mostly mothers (88 %; see Table 2). Similar to the Australian population[28], our sample comprised 24 % of children and 57 % of adults with overweight/obesity. The average family SEP (0·18) suggested a slightly more advantaged sample than the wave 6

**Table 2.** Characteristics of analytic sample (Mean values and standard deviations)

| | Children (*n* 1760) | | Adults (*n* 1812) | |
|---|---|---|---|---|
| Characteristics | Mean* | SD | Mean* | SD |
| Male (%) | 50·6 | | 12·2 | |
| Age (years) | 11·5 | 0·5 | 43·7 | 5·2 |
| BMI *z*-score | 0·30 | 0·99 | | |
| BMI (kg/m$^2$) | | | 27·8 | 6·1 |
| Overweight/Obese (%) | 24 | | 57 | |
| Family socio-economic position† | 0·18 | 0·99 | 0·18 | 0·99 |
| Neighbourhood disadvantage | 1022 | 61 | 1023 | 61 |
| Highest education level (%) | | | | |
| Postgraduate degree | | | 14 | |
| Graduate diploma/certificate | | | 11 | |
| Bachelor degree/advanced diploma | | | 42 | |
| Certificate I–IV (including trades) | | | 31 | |
| Inflammatory diet scores (range) | | | | |
| Literature-derived (range 5–14) | 2·51 | 3·05 | 0·76 | 2·46 |
| GlycA-derived (range −0·15–0·42) | 0·06 | 0·06 | 0·03 | 0·06 |
| Mental health measures (range) | | | | |
| HRQL (0–1) | 0·82 | 0·15 | 0·89 | 0·09 |
| Psychosocial QoL (0–1) | | | 0·47 | 0·16 |
| Psychosocial health (0–100) | 77·19 | 13·91 | | |
| Life satisfaction (0–100) | 83·42 | 13·42 | | |
| General well-being (0–100) | 82·99 | 13·18 | | |

HRQL, Health-related Quality of Life; QoL, Quality of Life.
* Unless otherwise specified.
† SEP was drawn from LSAC Wave 6 assessments, conducted approximately 1 year prior to CheckPoint Neighborhood disadvantage: national mean 1000 (SD 100).

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LSAC cohort (SEP mean 0 (SD 1))[25]. Children's and adults' average literature-derived diet scores were 2·51 (SD: 3·05; range: −5 to 14) and 0·76 (SD: 2·46; range: −5 to 13), and their GlycA-derived scores were 0·06 (SD: 0·06; range: −0·14 to 0·42) and 0·03 (SD: 0·06; range −0·15 to 0·35), respectively. Mental well-being measures were in line with population norms for adults and children of this age.

### *Inflammatory diet and mental well-being*

Estimated causal effects calculated using the flexible approach were almost identical to the classical regression results. Thus, we not only focus on reporting classical regression models below but also report the more flexible effects in Table 3.

Higher inflammatory diet scores were associated with worse mental well-being in both age groups, with the literature-derived and GlycA-derived diet scores showing similar associations. For example, for negatively framed mental well-being in children, each SD increment in the literature-derived inflammatory diet score was associated with −0·19 (95 % CI −0·30, −0·08) to −0·27 (95 % CI −0·37, −0·18) lower mental well-being scores, with similar results for positively framed mental well-being (−0·15 (95 % CI −0·25, −0·05) to −0·24 (95 % CI −0·34, −0·13)). In adults, estimated effects for negatively framed mental well-being were similar to children, although associations were slightly stronger for the literature-derived inflammatory diet score compared with the GlycA-derived score.

Binary outcomes showed similar results (Table 3), with inflammatory diet scores associated with a higher relative risk of poor mental well-being (i.e. lowest 16th percentile) across all measures in both age groups. Associations were larger in adults, compared with children, and in adults, they were also slightly stronger for the literature-derived, compared with the GlycA-derived inflammatory diet score. For example, in adults, each SD increment in the literature-derived inflammatory diet score was associated with a 1·48 (95 % CI 1·10, 1·98) to 1·86 (95 % CI 1·42, 2·43) higher risk of poor mental well-being.

Among children, there was little evidence to suggest that BMI mediated effects of a pro-inflammatory diet on mental well-being (Table 4). However, among adults, the percentage mediation by BMI ranged from 19 % to 21 % for the literature-derived score, and 39–40 % for the GlycA-derived score.

## Discussion

### *Principal findings*

In both children and mid-life adults, a diet with greater overall inflammatory potential was associated with worse mental well-being across the spectrum. The consistency of these associations across all mental well-being measures, with both the inflammatory diet scores, and within both age groups, provides confidence in the results that an inflammatory diet worsens mental well-being.

Estimated effects were largest for the psychosocial QoL measures in both children and adults. This may reflect that these measures have a more specific focus on mental health constructs, rather than on general well-being. It may also be a reflection of greater detail gained from more items (i.e. twenty-five items

**Table 3.** Causal linear regression analyses comparing diet score above 75th percentile with others

| | Children | | | | | | Adults | | |
|---|---|---|---|---|---|---|---|---|---|
| Diet Score | HRQL (CHU9D) | | Psychosocial QoL (PedsQL-PS) | | General well-being (PedsQL-GW) | Life satisfaction (ISCWeb) | HRQoL (CHU9D) | | Psychosocial QoL (AQoL8D-PS) |
| **Standardised mean difference (95 % CI) in children/adults** | | | | | | | | | |
| Classic linear regression models | | | | | | | | | |
| Literature | −0·26 | −0·36, −0·16 | −0·27 | −0·37, −0·18 | −0·15 | −0·25, −0·05 | −0·16 | −0·26, −0·06 | −0·24 | −0·34, −0·14 | −0·39 | −0·48, −0·29 |
| Data | −0·19 | −0·30, −0·08 | −0·25 | −0·35, −0·14 | −0·21 | −0·32, −0·10 | −0·24 | −0·35, −0·13 | −0·19 | −0·31, −0·08 | −0·28 | −0·39, −0·18 |
| Flexible linear regression models | | | | | | | | | | | | |
| Literature | −0·26 | −0·36, −0·16 | −0·27 | −0·37, −0·18 | −0·16 | −0·26, −0·06 | −0·16 | −0·26, −0·06 | −0·24 | −0·34, 0·14 | −0·39 | −0·48, −0·29 |
| Data | −0·18 | −0·29, −0·07 | −0·27 | −0·38, −0·16 | −0·23 | −0·34, −0·12 | −0·27 | −0·38, −0·16 | −0·20 | −0·31, −0·08 | −0·31 | −0·42, −0·20 |
| **Relative risk (95 % CI) in children/adults** | | | | | | | | | | | | |
| Classic log-binomial regression models | | | | | | | | | | | | |
| Literature | 1·44 | 1·15, 1·79 | 1·57 | 1·25, 1·99 | 1·51 | 1·19, 1·92 | 1·48 | 1·17, 1·86 | 1·54 | 1·18, 2·02 | 1·86 | 1·42, 2·43 |
| Data | 1·35 | 1·06, 1·70 | 1·33 | 1·04, 1·70 | 1·67 | 1·31, 2·14 | 1·67 | 1·32, 2·11 | 1·48 | 1·10, 1·98 | 1·63 | 1·22, 2·18 |
| Flexible log-binomial regression models | | | | | | | | | | | | |
| Literature | 1·45 | 1·14, 1·77 | 1·52 | 1·18, 1·86 | 1·44 | 1·11, 1·77 | 1·42 | 1·10, 1·73 | 1·43 | 1·12, 1·75 | 1·65 | 1·30, 2·00 |
| Data | 1·39 | 1·07, 1·71 | 1·38 | 1·06, 1·71 | 1·59 | 1·21, 1·96 | 1·62 | 1·24, 1·99 | 1·42 | 1·08, 1·76 | 1·52 | 1·17, 1·87 |

HRQL, Health-related Quality of Life; QoL, Quality of Life; SEIFA, neighbourhood disadvantage; SEP, socio-economic position.
All models adjusted for age, sex, SEP, SEIFA and parental education.

**Table 4.** Direct/indirect effects of pro-inflammatory diet (>75th percentile *v.* Others) on mental well-being through BMI (Risk ratios (RR) and 95 % confidence intervals)

| | Exposure: literature-derived diet score | | | | | | Exposure: GlycA-derived diet score | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Children | | | Adults | | | Children | | | Adults | | |
| | *RR | 95 % CI | *P* | *RR | 95 % CI | *P* | *RR | 95 % CI | *P* | *RR | 95 % CI | *P* |
| HRQL (CHU9D) | | | | | | | | | | | | |
| Indirect effect | 1·00 | 0·99, 1·02 | 0·78 | 1·07 | 1·03, 1·11 | **<0·01** | 1·00 | 0·99, 1·00 | 0·86 | 1·12 | 1·06, 1·19 | **<0·001** |
| Direct effect | 1·54 | 1·19, 2·00 | **<0·01** | 1·37 | 1·05, 1·79 | 0·02 | 1·45 | 1·10, 1·91 | **<0·01** | 1·24 | 0·92, 1·66 | 0·15 |
| Total effect | 1·55 | 1·19, 2·01 | **<0·01** | 1·47 | 1·13, 1·92 | **<0·01** | 1·45 | 1·10, 1·91 | **<0·01** | 1·39 | 1·04, 1·86 | 0·03 |
| Proportion mediated by BMI | 0·6 % | | | 20·9 % | | | N/A | | | 39·3 % | | |
| Psychosocial QoL (PedsQL-PS) | | | | | | | | | | | | |
| Indirect effect | 1·00 | 0·98, 1·01 | 0·63 | | | | 1·00 | 0·99, 1·00 | 0·88 | | | |
| Direct effect | 1·69 | 1·29, 2·20 | **<0·001** | | | | 1·43 | 1·08, 1·88 | 0·01 | | | |
| Total effect | 1·68 | 1·29, 2·20 | **<0·001** | | | | 1·43 | 1·08, 1·88 | 0·01 | | | |
| Proportion mediated by BMI | NA | | | | | | 0·1 % | | | | | |
| General well-being (PedsQL-GW) | | | | | | | | | | | | |
| Indirect effect | 0·96 | 0·93, 1·00 | 0·04 | | | | 1·00 | 0·97, 1·03 | 0·86 | | | |
| Direct effect | 1·68 | 1·28, 2·20 | **<0·001** | | | | 1·76 | 1·33, 2·32 | **<0·001** | | | |
| Total effect | 1·62 | 1·23, 2·13 | **<0·01** | | | | 1·76 | 1·33, 2·32 | **<0·001** | | | |
| Proportion mediated by BMI | NA | | | | | | 0·6 % | | | | | |
| Life satisfaction (ISCWeb) | | | | | | | | | | | | |
| Indirect effect | 0·98 | 0·96, 1·00 | 0·07 | | | | 1·00 | 0·98, 1·02 | 0·86 | | | |
| Direct effect | 1·58 | 1·21, 2·06 | **<0·01** | | | | 1·80 | 1·37, 2·37 | **<0·001** | | | |
| Total effect | 1·55 | 1·18, 2·02 | **<0·01** | | | | 1·80 | 1·37, 2·38 | **<0·001** | | | |
| Proportion mediated by BMI | NA | | | | | | 0·4 % | | | | | |
| Psychosocial QoL (AQoL8D-PS) | | | | | | | | | | | | |
| Indirect effect | | | | 1·59 | 1·21, 2·08 | **<0·01** | | | | 1·15 | 1·09, 1·23 | **<0·001** |
| Direct effect | | | | 1·09 | 1·04, 1·14 | **<0·001** | | | | 1·30 | 0·97, 1·74 | 0·08 |
| Total effect | | | | 1·73 | 1·32, 2·27 | **<0·001** | | | | 1·50 | 1·12, 2·00 | **<0·01** |
| Proportion mediated by BMI | | | | 19·1 % | | | | | | 39·9 % | | |

HRQL, Health-related Quality of Life; QoL, Quality of Life; SEP, socio-economic position.
Estimates adjusted for age, sex, SEP, neighbourhood disadvantage and parental education.
*RR represents effect estimates for direct, indirect, and total effect derived from causal mediation analysis, compared with the reference group. The proportion of the total effect mediated by BMI was calculated as RRDE(RRIE−1)/(RRDERRIE−1); if direct (DE) and indirect effect (IE) have opposite direction of association, the proportion will not be calculated and marked as NA.
Boldface indicates statistical significance ($P < 0·01$, $P < 0·001$).

included for adults and fifteen items for children) compared with the other briefer measures (i.e. 5–9 items).

BMI did not mediate effects between an inflammatory diet and mental well-being in children and accounted for between about 20 % (literature-derived) and about 39 % (GlycA-derived) of the direct effects for adults. Therefore, regardless of the pathway between diet, BMI and mental health, these mediation results suggest that diet may more directly affect mental health. That is, the associations between diet and mental health might be the direct result of inflammation or additional factors may lie on the pathway linking inflammatory diet and poor mental well-being. For example, there are various molecular mechanisms that link dietary factors with brain health[29], such as changes in circadian rhythm, hormonal homoeostasis and neuronal plasticity. In addition, high intake of inflammatory foods may affect the brain by negatively affecting the gut microbiota composition[30], including loss of microbial diversity and function that can impact physical and mental health.

### *Interpretation in light of previous research*

Our results align with the majority of previous research conducted with the DII, showing that a diet with greater inflammatory potential is associated with worse mental health among adults[1,3,31] and with stress in adolescents[6]. We extend these findings to a cross-sectional study of a population-derived cohort of both children and adults, using two somewhat cruder measures of an inflammatory diet, but broader measures of mental well-being, which included positively framed measures in children. Our results in children are congruent with Phillips and colleagues' findings in adults[5], in that we showed a diet with higher inflammatory potential is associated with lower positively framed well-being in children. Because our study was cross-sectional, we cannot directly interpret the results alongside previous longitudinal studies[3] or randomised controlled trials in adults[2], nor can we conduct comparable mediation analysis[7]. However, we note that longitudinal mediation analysis will be possible as the LSAC waves progress in future years and continue to assess adolescent and parental BMI and mental well-being.

### *Strengths and limitations*

Strengths of our study include its large, population-based sample of both children and mid-life adults, enhancing generalisability. Combining both pro- and anti-inflammatory dietary items into one inflammatory score gives a more accurate representation of dietary habits by better capturing overall inflammatory potential than looking at anti-inflammatory or pro-inflammatory diet alone. Widely used and validated measures of mental well-being also provide confidence that the measures are indicative

of the designed concepts and provide scope for comparison with future studies. Another strength included the incorporation of measures that reflect the positive spectrum of mental well-being by assessing positively framed questions in children – unfortunately, we were unable to look at this in adults.

Our results in adults may not generalise to men and to mid-life adults without children, given that most were parents who attended the sessions with their child and 88 % were women. Similarly, our findings may not generalise to those from highly disadvantaged backgrounds whose diets and mental health may be different to the CheckPoint cohort. Habitual diet is inherently difficult to measure[32] and like the majority of self-report diet assessments, the NaSSDA does not capture portion sizes or cooking methods and is subject to social desirability and recall biases[32]. Furthermore, because we only measured the intake of twenty-three dietary items, we were unable to generate the well-used DII[4]. However, our approach illustrates a low-burden approach (using brief FFQ) to potentially investigate similar questions in large cohorts. Another limitation is that children's data-derived inflammatory diet algorithm relied on adult data, which assumes foods and drinks have the same inflammatory potential for both age groups. In addition, given that we examined inflammatory diet scores dichotomously, we cannot rule out misclassification of the exposure. However, the use of a binary exposure simplifies the translation of our findings to public health and policy statements.

Furthermore, the study's cross-sectional nature limits identifying temporal relationships between inflammatory diet patterns and mental well-being. However, given that randomised controlled trials show that reducing inflammatory diets can reduce mental illness, such as depression[2], we have assumed directionality from diet to mental well-being and used the best possible causal modelling approaches to assess this. Even though we wanted to examine the causal relationship between an inflammatory diet and mental well-being and used causal modelling approaches, one can never be sure that the associations found are indeed causal and all interpretations are open to alternative reasons for these associations.

### *Implications*

Findings have important implications for understanding the origins of mental well-being and for policymakers designing strategies to tackle poor diet and mental well-being. However, shifting overconsumption of inflammatory diets is no easy task. Individual-level interventions to optimise diet are rarely sustained, and evidence-based societal level policies (e.g. sugar taxes)[33] fail to be implemented[34].

The overwhelming lack of success translating dietary intervention to policy has led to novel ideas, such as tackling diets high in inflammatory foods (e.g. red meat) from the perspective of climate change/sustainability. To improve dietary choices and their adverse impacts on mental well-being and physical health clearly requires political will[34], and far greater investments in preventative efforts[35] early in the life course. However, the benefits of doing so could extend well beyond mental well-being, to all aspects of human health and the natural systems on which it depends[34].

### *Conclusions*

Inflammatory diet patterns were cross-sectionally associated with mental well-being at age 11–12 years, with similar effects observed in mid-adulthood. Findings highlight the benefits associated with a low inflammatory diet beyond physical health, which begin at 11–12 years of age, and may emerge earlier. This highlights yet another compelling reason to urgently address inflammatory diets early in life.

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K. L. led this study as the primary supervisor of D. J. W., she contributed to the study design, analysis of the data, interpretation of data and revised the article critically for important intellectual content. D. J. W. initiated this work as part of a student project, made substantial contributions to the conception and design of the study, and revised it critically. M. L. conducted the data analysis, contributed to the interpretation of data and revised the article critically for important intellectual content. A. G. oversaw the analysis of data, contributed to the interpretation of data and revised the article critically for important intellectual content. D. P. B. and L. A. B. are Investigators on the Child Health CheckPoint study; they made contributions to the study design, interpretation of data and revised the article critically for important intellectual content. R. L. and K. L. made contributions to the study design, contributed to the interpretation of data and



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revised the article critically for important intellectual content. M. W. and J. A. K. are Investigators on the Child Health CheckPoint study, they made major contributions to the study design, co-supervised D. J. W.'s student project, contributed to the interpretation of data and revised the article critically for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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## Supplementary material

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