Association between diet quality in adolescence and adulthood and knee symptoms in adulthood: a 25-year cohort study

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Short title: Diet quality and knee symptoms

Key words Diet quality, adolescence, adulthood, knee symptoms, osteoarthritis
Abstract

We aimed to describe associations between diet quality in adolescence and adulthood and knee symptoms in adulthood. 275 participants had adolescent diet measurements, 399 had adult diet measurements, and 240 had diet measurements in both timepoints. Diet quality was assessed by Dietary Guidelines Index (DGI), reflecting adherence to Australian Dietary Guidelines. Knee symptoms were collected using Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Data were analysed using zero-inflated negative binomial regressions. The overall adolescent DGI was not associated with adult knee symptoms, although lower intake of discretionary foods (e.g. cream, alcohol, bacon, and cake) in adolescence was associated with lower pain (Mean ratio (MR): 0.96) and dysfunction (MR: 0.94). The overall adult DGI was not associated with knee symptoms; however, limiting saturated fat was associated with lower WOMAC (Pain: MR 0.93; stiffness: MR 0.93; dysfunction: MR 0.91), drinking water was associated with lower stiffness (MR 0.90) and fruit intake was associated with lower dysfunction (MR 0.90). Higher DGI for dairy in adulthood was associated with higher WOMAC (Pain: MR 1.07; stiffness: MR 1.13; dysfunction: MR 1.11). Additionally, the score increases from adolescence to adulthood were not associated with adult knee symptoms, except for associations between score increase in limiting saturated fat and lower stiffness (MR 0.89) and between score increase in fruit intake and lower dysfunction (MR 0.92). In conclusion, the overall diet quality in adolescence and adulthood were not associated with knee symptoms in adulthood. However, some diet components may affect later knee symptoms.
Introduction

Knee osteoarthritis (OA) is the most prevalent joint disease worldwide, and is associated with pain, stiffness and loss of function. However, no disease-modifying treatments are available \(^{(1)}\). Although knee OA is commonly diagnosed among middle-aged or older population, the disease process can start during earlier life. Studies have found that the prevalence of knee pain can even exceed 30% among adults aged 30-40 years \(^{(2)}\). The knee symptoms may be one of the early risk factors of knee OA in later life \(^{(3)}\). A systematic review indicated that the evidence from well-conducted case-control studies supported knee pain was a predisposing factor of knee OA, though there was a paucity of well-designed cohort studies \(^{(4)}\). Thus, identifying factors affecting knee symptoms among adults aged about 30-40 years may be important for developing prevention strategies and management of knee OA.

Diet is important in disease prevention (e.g. cardiovascular diseases), as the foods consumed in daily life could have beneficial or detrimental effects on our health \(^{(5; 6; 7; 8)}\). Two approaches are generally employed in data analysis of diet: hypothesis-oriented approaches (reflecting the adherence to guidelines or recommendations, e.g. dietary score) and exploratory approaches, which focus on study-specific data, e.g. principal component analysis \(^{(9; 10)}\). Hypothesis-oriented approaches have advantages over exploratory approaches as they are based on existing knowledge of optimal diet and provide clear information about healthy levels \(^{(11)}\). Several studies have reported associations between daily diet assessed by dietary score and knee OA in older adults with knee OA or at risk of OA. Cross-sectionally, adherence to a Mediterranean diet was associated with lower knee pain \(^{(12)}\) and lower prevalence of knee OA \(^{(13)}\); longitudinally, adherence to a Mediterranean diet was associated with lower risk of knee pain worsening and lower incidence of symptomatic knee OA \(^{(14)}\). However, no studies have assessed the effect of diet on knee symptoms in younger adults,
who are an important target group for disease prevention. Moreover, the Mediterranean diet index was defined according to dietary habits\textsuperscript{(15)}, but not a national dietary guideline which represents the most recommended diet based on current evidence.

Therefore, we aimed to describe associations between diet quality (as assessed by adherence to national dietary guidelines) in adolescence and adulthood and knee symptoms in adulthood.

Methods
Participants
In 1985, The Australian Schools Health and Fitness Survey (ASHFS) was conducted to provide benchmark data on the health and fitness of Australian schoolchildren/adolescents (7-15 years, n=8498) with a nationally representative sample. Two-stage probability sampling was used for the ASHFS to randomly select schools and then children/adolescents within age groups in schools. Students aged 10-15 years completed the 24 hour diet record in adolescence and represent the adolescent cohort in the current analysis. The Childhood Determinants of Adult Health (CDAH) Study was a 20-year follow-up of children/adolescents who participated in the ASHFS. During 2004-2006, participants (aged 26-36 years) completed the food frequency questionnaire (FFQ) and food habits questionnaire (FHQ) and attended clinics (n=2410) which were located at sites in major cities and regional centres around Australia and represent the adulthood cohort in the current analysis. The CDAH Knee Cartilage Study was a 4-5 year follow-up of the CDAH study. During 2008-2010, participants residing in metropolitan Melbourne and Sydney were invited to attend a computer-assisted telephone interview as part of the CDAH Knee Cartilage Study. The exclusion criteria included: being pregnant, having other forms of arthritis, having contraindications of magnetic resonance imaging (MRI), and finally 449 participants (aged
31-41 years) participated and completed the knee symptom questionnaire. The detailed reasons for non-participation in the CDAH Knee Cartilage Study included: 1646 did not reside in Melbourne or Sydney, 235 did not respond or refused, 3 were pregnant during the CDAH Knee Cartilage Study, 2 had rheumatoid arthritis, 13 had contraindications of MRI, and 62 withdrew. The details of enrolment of ASHFS, CDAH, and the CDAH Knee Cartilage Study have been published elsewhere \(^2\); \(^{16}\). In the current analysis, 275 of the 449 with a knee symptom questionnaire had adolescent diet measurements when they were aged 10-15 years in ASHFS, 399 had eligible adult diet measurements (14 were pregnant when diet data was collected and 36 missed >10% FFQ item responses or key FHQ responses), resulting in 240 with eligible diet measurements in both adolescence and adulthood (Figure 1).

This study was approved by the Southern Tasmania Health and Medical Human Research Ethics Committee (HREC), the Monash University HREC and the Northern Sydney and Central Coast Area Health HREC. All participants provided written informed consent.

**Anthropometric measurements**

Weight was measured to the nearest 0.5 kg in 1985 and 0.1 kg at follow-up (with shoes and bulky clothing removed) using a scale (Heine, Dover, NH). Height was measured to the nearest 0.1 cm (with shoes and socks removed) using a stadiometer (Invicta, Leicester, UK). Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared.

**Dietary measurements**

In ASHFS, participants recorded the time and estimated amount of each food or drink item consumed during a 24-hour period. Trained data collectors showed the adolescents how to fill
out the food record, and each adolescent was interviewed on collection of the records to check and clarify the entries. The paper questionnaires were manually processed in 1985 to provide the gram weight and the kilojoule energy content of each food or beverage item. The energy content of each item was determined using a specially compiled database of the nutrient composition of Australian foods\(^{(17)}\). The data for each item was used for this current study to calculate the proportion of a standard serving as defined in the 2013 Australian Dietary Guidelines\(^{(18)}\). For example, if a participant reported consuming 60 g of toast at breakfast in the ASHFS food record, this equates to 1.5 standard 40-g servings of bread. In CDAH, participants completed a 127-item FFQ and an FHQ, and the paper questionnaires were scanned using Teleform (version 9.0). Each frequency reported in the FFQ was assumed to be a standard serving defined in the 2013 Australian Dietary Guidelines\(^{(18)}\). For example, if a participant reported eating breakfast cereal once per day, this was assumed to be one standard 30-g serving of grains. Dietary Guidelines Index (DGI) and total energy intake were calculated based on the consumed servings. The DGI comprises 9 indicators and the maximum possible score was 100. A higher score indicated higher diet quality (higher adherence to Australian Dietary Guidelines). Seven indicators, worth 10 points each, related to recommended minimum intakes (dietary variety, vegetables, fruit, grains, lean meats and alternatives, low-fat dairy and alternatives, water). For example, a participant scored 10 for fruit intake if they consumed at least 2 servings of fruit as guideline recommended. Participants could receive proportional scores for partially meeting the recommendations. Two indicators were for lower intake of discretionary foods (20 points), including foods high in saturated fat (e.g. cream), alcohol, added salt (e.g. bacon), and added sugars (e.g. cake), and limiting saturated fats (10 points). The details of DGI measures has been published elsewhere\(^{(11)}\). The changes in diet quality from adolescence to adulthood were represented by
the score changes of DGI and its components (scores in adulthood minus the corresponding scores in adolescence).

**Physical activity measurements**

In ASHFS, participants self-reported past week duration and frequency of discretionary sport or exercise (leisure activity), walking and cycling to and from school (transport activity), school physical education and school sport. For each activity, frequency was multiplied by duration to estimate minutes per week, and activities were summed to estimate total physical activity. In CDAH, physical activity was assessed using the long version of the International Physical Activity Questionnaire. Participants were asked to report the total time and frequency of occupational, commuting, domestic and leisure activity during the past week. Physical activities were calculated by multiplying frequency by duration to estimate minutes per week of vigorous, moderate and walking activity. Time spent in each domain was summed to estimate total physical activity.

**Knee symptom measurements**

The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) is widely used for evaluating clinically important symptoms in OA patients (19). WOMAC has also shown adequate responsiveness, content, and construct validity for evaluating knee complaints in adolescents and adults (20). In CDAH Knee Cartilage Study, participants completed a questionnaire, including WOMAC. Knee pain, stiffness, and dysfunction during the past 30 days were assessed on a scale of 0–9 for each subscale, where 0 indicated no complaints and 9 indicated the maximum intensity of the complaint. WOMAC pain, stiffness, and dysfunction were assessed in 5, 2, and 17 subscales, respectively. WOMAC scores were calculated by adding the score of subscales in each domain. The maximum possible scores of
pain, stiffness and dysfunction were 45, 18, and 153, respectively. A non-zero score indicates the presence of knee symptom. Knee injury history was also recorded in the questionnaire.

**Statistical analyses**

Mean (standard deviation), number (percentage), and median (interquartile range) were used to describe the characteristics of the participants. Zero-inflated negative binomial regression analyses were used to assess the associations between diet quality and knee symptoms and estimate the mean ratios, as there are exceeded zeros in the knee symptom data and the sample variances significantly exceeded the sample means (over-dispersion)\(^{(21; 22)}\). Age, sex, BMI, physical activity, total energy intake, and knee injury history were included as potential confounders based on biological plausibility. A p-value less than 0.05 (2-tailed) was considered as statistical significance. All statistical analyses were performed in Stata (Texas, USA), version 16.0.

**Results**

Among the participants included in data analysis, the average adolescent and adult age with dietary data was 12.6±1.8 and 30.9±2.8 years, and the average adolescent and adult DGI was 46.5±12.6 and 55.4±11.3, respectively. The prevalence of knee pain, stiffness and dysfunction (at mean aged 35.4 years) was 35.1% (30.4%, 40.0%), 31.6% (27.0%, 36.4%) and 39.9% (35.1%, 44.8%), respectively (Table 1).

Overall adolescent DGI was not associated with knee pain, stiffness, or dysfunction in adulthood (Table 2). Similarly, most DGI components (vegetable, food variety, fruit, grain, lean protein, dairy, water, limiting saturated fat) were not associated with adult knee
symptoms, although higher score for lower intake of discretionary foods in adolescence was significantly associated with lower knee pain and dysfunction in adulthood (Table 2).

Overall adult DGI and some DGI components (vegetable, food variety, grain, lean protein, lower intake of discretionary foods) were not associated with knee pain, stiffness, or dysfunction in adulthood (Table 3). However, higher score for limiting saturated fat in adulthood was significantly associated with lower WOMAC pain, stiffness and dysfunction (Table 3). In addition, higher score for drinking water was significantly associated with lower stiffness and higher score for fruit intake was significantly associated with lower dysfunction (Table 3). In contrast, higher DGI score for dairy intake was significantly associated with higher WOMAC pain, stiffness and dysfunction (Table 3).

The changes of overall DGI and most of the component scores (vegetable, food variety, grain, lean protein, dairy, water, lower intake of discretionary foods) from adolescence to adulthood were not associated with knee pain, stiffness, or dysfunction in adulthood (Table 4). However, the change of component score for limiting saturated fat from adolescence to adulthood was associated with lower stiffness, and the change score for fruit intake was associated with lower dysfunction in adulthood (Table 4).

**Discussion**

This is the first study describing the associations between diet quality in adolescence and adulthood and knee symptoms in adulthood. We found overall DGI and a large number of DGI components in adolescence and adulthood and their changes from adolescence to adulthood were not associated with knee symptoms in adulthood. However, several DGI components (lower intake of discretionary foods in adolescence, limiting saturated fat, fruit
intake, and water intake in adulthood) were associated with lower knee symptoms, whereas higher DGI score for dairy in adulthood was associated with higher knee symptoms. Moreover, the change of DGI score from adolescence to adulthood for limiting saturated fat was associated with lower stiffness and the change of DGI score for fruit intake was associated with lower dysfunction.

We did not find significant associations between the overall DGI in adolescence and adulthood and knee symptoms in adulthood. The negative results may be because the effects from the different DGI components were different. Although some components (e.g. limiting saturated fat in adulthood) were associated with lower knee symptoms, the effects may be neutralized by another component (e.g. dairy) which has the opposite effects. Our results were consistent with a previous review, which suggested that different nutrients could have antagonistic effects on a chronic disease (10).

We found that eating only lower amounts of discretionary foods in adolescence, independent of BMI, was associated with lower knee pain and dysfunction in adulthood, which has not been reported in previous studies. Consuming greater amounts of discretionary foods has been associated with metabolic diseases (e.g. type 2 diabetes) in young adults (23), and the associations may even persist after adjustment for BMI (24; 25). Knee OA shares many causal pathways with these metabolic diseases (26). Thus, eating lower amounts of discretionary foods may have beneficial effects on knee joint by reducing activation of causal pathways for metabolic diseases. These beneficial effects were only associated with adolescent diets not adult diets, even though the sample size was larger in adulthood than that in adolescence. The reason is unclear but may suggest eating lower discretionary foods is particularly important in adolescence and could have long-term effects.
We found limiting saturated fat in adulthood was associated with lower knee pain, stiffness and dysfunction in adulthood. The underlying mechanism may be the decreased detrimental effects from saturated fat and/or increased beneficial effects from unsaturated fat on knee joint. Although there are no similar studies based on younger adult populations, some studies have reported that intake of saturated fat was associated with knee structural signs of OA in middle-aged healthy adults (27) and knee OA structural progression in patients with radiographic knee OA (28). In addition, intake of unsaturated fat could have protective effects on knee structures (29) and symptoms (pain and function) (30; 31) among patients with knee OA.

We found that intake of fruit in adulthood was associated with lower knee dysfunction in adulthood, which is partly consistent with previous trials. The trials reported that freeze-dried strawberry powder (32) and freeze-dried blueberry powder (33) could reduce pain and dysfunction in adults with knee OA. However, we did not find evident effects on pain or stiffness; the reason may be that not all fruits have the same analgesic effects as berries (32). We also found water intake in adulthood was associated with low stiffness in adulthood. Drinking plenty of water has been associated with lower risk of chronic diseases, such as type 2 diabetes (34), suggesting its potential benefits on metabolic fitness. The underlying mechanism of our results warrants further studies but may have some shared metabolic pathways between diabetes and knee OA (35).

Our finding that dairy score was associated with higher knee pain, stiffness and dysfunction should be interpreted cautiously. Previous studies reported that milk consumption (any kind) was associated lower prevalence of symptomatic knee OA cross-sectionally (36) and less radiographic OA progression (decrease of joint space width) longitudinally (37). However, the
effects from specific kinds of milk (full-fat and skimmed milk) were not identified. A third
study reported that the consumption of full-fat dairy, but not skimmed dairy, was associated
with lower prevalence of knee OA\(^{38}\). In our DGI calculation, the dairy score was made up
of 2 parts: 5 points were allocated for amounts of dairy (any kind), and 5 for whether it was
reduced fat\(^{11}\). Therefore participants consuming full-fat dairy would get lower dairy scores
than those consuming skimmed-dairy, however, they may get beneficial effects on knee
symptoms from consuming full-fat dairy.

We also found the change of score for limiting saturated fat was associated with lower
stiffness and the change of score for fruit intake was associated with lower dysfunction. As
diet was measured with a 24-hour food record in adolescence and an FFQ in adulthood, it is
not clear if the change scores represent the improvements of diet quality, or are the results of
different dietary measurement methods. Moreover, the sample size decreased in these
analyses due to fewer participants having eligible diet measurements in both adolescence and
adulthood. This means that we have less power to find statistically significant results,
although some effect sizes in our results were relatively large (e.g. association between the
score change for limiting saturated fat and knee pain). Therefore, further studies are needed to
verify and interpret our results.

We observed that the significant associations between diet components and knee symptoms
were largely evident in adulthood. This is in line with our previous study, where the effect of
adult adiposity measures on knee structures in adults were much more evident than that of
adolescent adiposity measures\(^{39}\). Adolescent diet could be changeable during growth, so it
may only have a few residual effects. Moreover, the single 24-hour food record may not fully
reflect the daily adolescent diet.
Our study has some strengths. First, this study used the 25-year prospective data from adolescence to adulthood and this is the first study focusing on knee symptoms in adults who are important in knee OA prevention. Second, the use of DGI represented the adherence to the Australian dietary guidelines, and the core recommendations of these national guidelines are consistent with most dietary guidelines worldwide \(^{(40)}\). Third, our results have been adjusted for important potential confounders, including total energy intake and BMI. Some limitations of our study should be considered. First, the current sample size was determined by the available data from original cohort (ASHFS). A formal power calculation for sample size was not performed because this was a secondary analysis of the data collected in the main study. We only had a modest sample size due to the low proportion of participants who could be included in analyses. In particular, the adolescent dietary measures were only collected among adolescents aged 10-15 years, but not the whole cohort (aged 7-15 years). Participants in the current study were 1.8 year older and 0.8 kg/m\(^2\) higher in BMI than those in the remainder of the ASHFS, whereas female proportions were comparable. Thus, the generalizability of our results may be limited, and further confirmatory studies are needed. Second, we only collected knee symptom data once, so we were unable to describe longitudinal changes in knee symptoms. Third, the dietary data were collected using different measurements (the 24-hour food record for adolescence and the 127-item FFQ for adulthood), which necessitated different methods of scoring the DGI components. The different scoring methods may introduce bias in calculating the longitudinal changes of DGI. In adolescence, only a single 24 hour food record was taken, whereas multiday food records may be more accurate, as they may be more reflective of daily diet. Reassuringly, this method has been suggested to be extremely valuable in collecting children’s diet data despite its flaws \(^{(41)}\). In adulthood, the FFQ only collected data on frequency of food consumption, and each
frequency was assumed to be a standard serving, this may lead the inaccuracy in quantifying the food intake. However, the assignment of a constant portion size has been validated in epidemiologic studies, though it may result in a reduction of interindividual variance (42).

Fourth, we did not collect the data regarding family history of knee OA and bleeding disorders history, which may have impacts in the development of knee OA, so we were unable to assess their potential effects on our findings.

In conclusion, the overall diet quality in adolescence and adulthood were not associated with knee symptoms in adulthood. However, some diet components such as limiting saturated fat in adulthood may affect later knee symptoms.
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Conflicts of interest None.

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Author contributions All authors participated in the study conception and design, acquisition of data, analysis and interpretation of data, preparation of manuscript, approved the manuscript for submission and publication, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
Reference


Table 1. Characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Adolescence (n=275)</th>
<th>Adulthood (n=399)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (year)</td>
<td>12.6 (1.8)</td>
<td>30.9 (2.8)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>131 (47.6)</td>
<td>193 (48.4)</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>19.0 (2.4)</td>
<td>25.0 (4.0)</td>
</tr>
<tr>
<td>Physical activity (hours/week), median (IQR)</td>
<td>7.6 (3.1, 9.8)</td>
<td>9.3 (5.6, 15.9)</td>
</tr>
<tr>
<td>Total energy intake (kJ/day)</td>
<td>8753 (3019)</td>
<td>8640 (2646)</td>
</tr>
<tr>
<td>Dietary Guideline Index (DGI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable (0-10)</td>
<td>3.7 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Food variety (0-10)</td>
<td>7.9 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Fruit (0-10)</td>
<td>5.5 (3.6)</td>
<td></td>
</tr>
<tr>
<td>Grain (0-10)</td>
<td>5.1 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Lean protein (0-10)</td>
<td>4.6 (3.3)</td>
<td></td>
</tr>
<tr>
<td>Dairy (0-10)</td>
<td>3.1 (2.1)</td>
<td></td>
</tr>
<tr>
<td>Water (0-10)</td>
<td>6.4 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Lower intake of discretionary foods (0-20)</td>
<td>3.5 (6.8)</td>
<td></td>
</tr>
<tr>
<td>Limiting saturated fat (0-10)</td>
<td>6.7 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Overall adolescent DGI (0-100)</td>
<td>46.5 (12.6)</td>
<td></td>
</tr>
<tr>
<td>Estate Guideline Index (DGI)</td>
<td></td>
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</tr>
<tr>
<td>Vegetable (0-10)</td>
<td>4.1 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Food variety (0-10)</td>
<td>5.6 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Fruit (0-10)</td>
<td>7.1 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Grain (0-10)</td>
<td>5.7 (2.4)</td>
<td></td>
</tr>
<tr>
<td>Lean protein (0-10)</td>
<td>8.3 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Dairy (0-10)</td>
<td>7.3 (2.9)</td>
<td></td>
</tr>
<tr>
<td>Water (0-10)</td>
<td>7.7 (1.9)</td>
<td></td>
</tr>
<tr>
<td>Lower intake of discretionary foods</td>
<td>2.3 (5.3)</td>
<td></td>
</tr>
<tr>
<td>Limiting saturated fat (0-10)</td>
<td>7.3 (2.7)</td>
<td></td>
</tr>
<tr>
<td>Overall adult DGI (0-100)</td>
<td>55.4 (11.3)</td>
<td></td>
</tr>
<tr>
<td>WOMAC (&gt;0), n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>140 (35.1)</td>
<td></td>
</tr>
<tr>
<td>Stiffness</td>
<td>126 (31.6)</td>
<td></td>
</tr>
<tr>
<td>Dysfunction</td>
<td>159 (39.9)</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean (SD) unless otherwise stated.

BMI, body mass index; IQR, interquartile range; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.
Table 2. Association between diet quality in adolescence and knee symptoms in adulthood. (n=275)

<table>
<thead>
<tr>
<th></th>
<th>Pain Mean ratio (95% CI)</th>
<th>Stiffness Mean ratio (95% CI)</th>
<th>Dysfunction Mean ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetable (0-10)</td>
<td>0.98 (0.93, 1.04)</td>
<td>1.01 (0.95, 1.07)</td>
<td>1.04 (0.95, 1.15)</td>
</tr>
<tr>
<td>Food variety (0-10)</td>
<td>0.97 (0.86, 1.10)</td>
<td>0.92 (0.80, 1.05)</td>
<td>1.08 (0.88, 1.32)</td>
</tr>
<tr>
<td>Fruit (0-10)</td>
<td>1.02 (0.96, 1.08)</td>
<td>0.95 (0.87, 1.05)</td>
<td>1.04 (0.95, 1.13)</td>
</tr>
<tr>
<td>Grain (0-10)</td>
<td>0.99 (0.90, 1.08)</td>
<td>0.95 (0.88, 1.03)</td>
<td>0.98 (0.89, 1.13)</td>
</tr>
<tr>
<td>Lean protein (0-10)</td>
<td>1.03 (0.96, 1.11)</td>
<td>0.93 (0.87, 1.01)</td>
<td>0.99 (0.90, 1.08)</td>
</tr>
<tr>
<td>Dairy (0-10)</td>
<td>1.02 (0.91, 1.14)</td>
<td>1.00 (0.89, 1.13)</td>
<td>1.09 (0.94, 1.27)</td>
</tr>
<tr>
<td>Water (0-10)</td>
<td>0.88 (0.76, 1.03)</td>
<td>0.95 (0.82, 1.11)</td>
<td>0.96 (0.81, 1.15)</td>
</tr>
<tr>
<td>Lower intake of discretionary foods (0-20)</td>
<td><strong>0.96 (0.92, 1.00)</strong></td>
<td>0.97 (0.93, 1.02)</td>
<td><strong>0.94 (0.90, 0.99)</strong></td>
</tr>
<tr>
<td>Limiting saturated fat (0-10)</td>
<td>0.87 (0.61, 1.24)</td>
<td>0.91 (0.64, 1.29)</td>
<td>0.69 (0.46, 1.04)</td>
</tr>
<tr>
<td>Overall DGI (0-100)</td>
<td>0.99 (0.97, 1.01)</td>
<td>0.98 (0.97, 1.00)</td>
<td>0.99 (0.97, 1.02)</td>
</tr>
</tbody>
</table>

Bold denotes statistical significance, p<0.05.

CI, confidence interval; DGI, Dietary Guidelines Index.

Adjusted for age, sex, body mass index, physical activity, total energy intake in adolescence, and knee injury history in adulthood.
Table 3. Association between diet quality in adulthood and knee symptoms in adulthood. (n=399)

<table>
<thead>
<tr>
<th></th>
<th>Pain</th>
<th>Stiffness</th>
<th>Dysfunction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ratio (95% CI)</td>
<td>Mean ratio (95% CI)</td>
<td>Mean ratio (95% CI)</td>
</tr>
<tr>
<td>Vegetable (0-10)</td>
<td>0.98 (0.91, 1.07)</td>
<td>0.96 (0.86, 1.07)</td>
<td>0.92 (0.80, 1.05)</td>
</tr>
<tr>
<td>Food variety (0-10)</td>
<td>1.03 (0.92, 1.16)</td>
<td>1.05 (0.93, 1.19)</td>
<td>0.98 (0.85, 1.14)</td>
</tr>
<tr>
<td>Fruit (0-10)</td>
<td>0.99 (0.91, 1.07)</td>
<td>1.00 (0.92, 1.08)</td>
<td><strong>0.90 (0.81, 0.99)</strong></td>
</tr>
<tr>
<td>Grain (0-10)</td>
<td>0.93 (0.87, 1.00)</td>
<td>1.05 (0.98, 1.13)</td>
<td>0.97 (0.88, 1.06)</td>
</tr>
<tr>
<td>Lean protein (0-10)</td>
<td>0.94 (0.80, 1.09)</td>
<td>0.94 (0.81, 1.10)</td>
<td>0.94 (0.77, 1.15)</td>
</tr>
<tr>
<td>Dairy (0-10)</td>
<td><strong>1.07 (1.00, 1.13)</strong></td>
<td><strong>1.13 (1.05, 1.21)</strong></td>
<td><strong>1.11 (1.02, 1.21)</strong></td>
</tr>
<tr>
<td>Water (0-10)</td>
<td>0.98 (0.90, 1.07)</td>
<td><strong>0.90 (0.83, 0.99)</strong></td>
<td>0.94 (0.85, 1.05)</td>
</tr>
<tr>
<td>Lower intake of discretionary foods (0-20)</td>
<td>1.02 (0.99, 1.05)</td>
<td>1.03 (0.99, 1.07)</td>
<td>1.03 (0.99, 1.09)</td>
</tr>
<tr>
<td>Limiting saturated fat (0-10)</td>
<td><strong>0.93 (0.87, 0.99)</strong></td>
<td><strong>0.93 (0.87, 0.99)</strong></td>
<td><strong>0.91 (0.83, 0.99)</strong></td>
</tr>
<tr>
<td>Overall DGI (0-100)</td>
<td>1.00 (0.98, 1.01)</td>
<td>1.01 (0.99, 1.03)</td>
<td>1.00 (0.98, 1.02)</td>
</tr>
</tbody>
</table>

Bold denotes statistical significance, p<0.05.

CI, confidence interval; DGI, Dietary Guidelines Index.

Adjusted for age, sex, body mass index, physical activity, total energy intake, and knee injury history in adulthood.
Table 4. Association between the change in diet quality and knee symptoms. (n=240)

<table>
<thead>
<tr>
<th>Per 1 score increase</th>
<th>Pain</th>
<th>Stiffness</th>
<th>Dysfunction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ratio (95% CI)</td>
<td>Mean ratio (95% CI)</td>
<td>Mean ratio (95% CI)</td>
</tr>
<tr>
<td>Vegetable</td>
<td>0.99 (0.94, 1.05)</td>
<td>0.96 (0.91, 1.02)</td>
<td>0.92 (0.85, 1.01)</td>
</tr>
<tr>
<td>Food variety</td>
<td>0.95 (0.84, 1.07)</td>
<td>1.04 (0.92, 1.18)</td>
<td>0.89 (0.75, 1.05)</td>
</tr>
<tr>
<td>Fruit</td>
<td>0.96 (0.91, 1.02)</td>
<td>1.02 (0.96, 1.09)</td>
<td><strong>0.92 (0.86, 0.99)</strong></td>
</tr>
<tr>
<td>Grain</td>
<td>0.93 (0.85, 1.01)</td>
<td>1.03 (0.95, 1.12)</td>
<td>1.04 (0.93, 1.17)</td>
</tr>
<tr>
<td>Lean protein</td>
<td>0.93 (0.86, 1.01)</td>
<td>1.10 (0.98, 1.23)</td>
<td>1.03 (0.91, 1.16)</td>
</tr>
<tr>
<td>Dairy</td>
<td>1.05 (0.98, 1.13)</td>
<td>1.07 (0.99, 1.14)</td>
<td>0.99 (0.90, 1.09)</td>
</tr>
<tr>
<td>Water</td>
<td>1.00 (0.87, 1.14)</td>
<td>0.86 (0.74, 1.00)</td>
<td>0.90 (0.76, 1.05)</td>
</tr>
<tr>
<td>Lower intake of discretionary foods</td>
<td>1.02 (0.99, 1.05)</td>
<td>1.04 (0.99, 1.08)</td>
<td>1.03 (0.99, 1.08)</td>
</tr>
<tr>
<td>Limiting saturated fat</td>
<td>0.94 (0.87, 1.01)</td>
<td><strong>0.89 (0.80, 0.98)</strong></td>
<td>0.93 (0.81, 1.07)</td>
</tr>
<tr>
<td>Overall DGI</td>
<td>0.99 (0.98, 1.01)</td>
<td>1.01 (0.99, 1.03)</td>
<td>0.99 (0.96, 1.02)</td>
</tr>
</tbody>
</table>

Bold denotes statistical significance, p<0.05.

CI, confidence interval; DGI, Dietary Guidelines Index.

Adjusted for sex, age, body mass index, physical activity, total energy intake in adolescence and adulthood, and knee injury history in adulthood.
**Figure legends**

Figure 1 Flowchart showing selection of the participants for current study from previous studies.

CDAH Study, Childhood Determinants of Adult Health Study; MRI, magnetic resonance imaging.

- 8498 participants (aged 7-15 years) enrolled in the 1985 Australian Schools Health and Fitness Survey.
- 1658 not traced
- 817 did not respond
- 767 refused
- 86 deceased
- 2760 did not complete clinical tests
- 2410 participants (aged 26-36 years) completed clinical tests in CDAH Study (2004-2006).
- 1646 did not reside in Melbourne or Sydney
- 235 did not respond or refused
- 3 pregnant in CDAH Knee Cartilage Study
- 2 rheumatoid arthritis
- 13 contraindication of MRI
- 62 withdrew
- 449 participants (aged 31-41 years) completed telephone interview in CDAH Knee Cartilage Study (2008-2010).
- 14 pregnant when diet data was collected
- 36 missed responses in questionnaires
- 275 participants had eligible diet measurements in adolescence (aged 10-15 years in 1985)
- 399 participants had eligible diet measurements in adulthood
- 240 participants had eligible diet measurements in both adolescence and adulthood
- 159 aged 7-9 years in 1985