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Total Diet Score as a valid method of measuring diet quality among older adults

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Abstract
Background and Objectives: This study aimed to determine the accuracy of a diet quality measurement tool, the Total Diet Score (TDS) using two validation methods; firstly the TDS calculated from a food frequency questionnaire (FFQ) was compared to the TDS calculated from weighed food records (WFRs); secondly the TDS was compared to a number of dietary biomarkers. Methods and Study Design: Data were collected from a population based cohort study located in the Blue Mountains region of Sydney, Australia. To compare dietary assessment tools, a sub sample of 75 subjects (aged 63 to 83 years) completed the FFQ and three, four-day WFRs at baseline. Fasting blood samples were collected from 2897 subjects at the first follow up in 1997-1999. TDS scores were calculated from both WFRs and FFQs. Methods to compare FFQ TDS scores to WFR TDS scores included paired t-tests, Pearson correlations, Bland-Altman plots, joint classification quartiles and weighted kappa scores. Linear regression analyses were used to assess the relationship between TDS and biomarkers. Results: No significant mean difference was found between FFQ TDS and WFRs TDS ($p=0.63$) with a significant positive correlation seen between the two methods ($r=0.75$, $p<0001$). The Bland-Altman method found no linear trend between the differences and means of TDS scores between the FFQ and WFR ($p=0.38$). A significant trend for higher serum vitamin B-12, serum folate, homocysteine and lower total cholesterol was found with increasing TDS. Conclusions: These findings suggest that the TDS is a useful tool for assessing diet quality in an older population.

Keywords
older, adults, method, valid, score, diet, total, measuring, quality, among

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Authors' contributions: PM and VF study concept and design; PM and VF acquisition of the data; JR and AS conducted data analysis; JR, AS and VF interpreted study findings; JR drafted the manuscript. JR, VF, AS, BG and PM critically revised draft versions of the manuscript.

ABSTRACT

Objectives: This study aimed to determine the accuracy of a diet quality measurement tool, the Total Diet Score (TDS) using two validation methods; firstly the TDS calculated from a food frequency questionnaire (FFQ) was compared to the TDS calculated from weighed food records (WFRs); secondly the TDS was compared to a number of dietary biomarkers. **Subjects/Methods**: Data were collected from a population based cohort study located in the Blue Mountains region of Sydney, Australia. To compare dietary assessment tools, a sub sample of 75 subjects (aged 63 to 83 years) completed the FFQ and three, four-day WFRs at baseline. Fasting blood samples were collected from 2897 subjects at the first follow up in 1997-1999. TDS scores were calculated from both WFRs and FFQs. Methods to compare FFQ TDS scores to WFR TDS scores included paired t-tests, Pearson correlations, Bland-Altman plots, joint classification quartiles and weighted kappa scores. Linear regression analyses were used to assess the relationship between TDS and biomarkers. **Results**: No significant mean difference was found between FFQ TDS and WFRs TDS (p=0.63) with a significant positive correlation seen between the two methods (r=0.75, p<0001). The Bland-Altman method found no linear trend between the differences and means of TDS scores between the FFQ and WFR (p=0.38). A significant trend for higher serum vitamin B12, serum folate, homocysteine and lower total cholesterol was found with increasing TDS. **Conclusions**: These findings suggest that the TDS is a useful tool for assessing diet quality in an older population.

Key Words: validation, diet quality, older adults, biomarkers, Total Diet Score

INTRODUCTION

Assessing diet quality, focusing on the diet as a whole versus studying single nutrients, has become increasingly popular; as nutrients are not eaten in isolation and nutrient bioavailability can be affected by the interaction of nutrients from other foods when eaten together.[1-4] As a result, a number of tools have been developed to assess diet quality and its effect on health outcomes. Previous evidence has suggested that adhering to recommended dietary guidelines, a marker of diet quality, plays a role in maintaining good health outcomes and may reduce the risk of developing chronic disease.[3,5-9]

The Total Diet Score (TDS) was developed to determine diet quality in an older Australian population, relating to adherence to the Dietary Guidelines for Australian Adults (DGAA).[10] The TDS differs from other diet quality indices that have been adapted and/or developed for

use in Australian adult populations in recent years as it includes the dietary guideline relating to achieving and maintaining a healthy weight through being physically active and eating according to one's energy needs.[4,11,12] This component is scored on the ratio of energy balance and level of physical activity. Previously published results from this cohort of older Australians, measuring diet quality through the TDS, have shown a significantly reduced risk of all-cause mortality after 15 years with better diet quality. It has also been reported that individuals with higher TDS were less likely to have chronic kidney disease and had improved microvascular health.[13-16]

There is currently no 'gold standard' available to validate diet quality scores, although predicting disease outcomes from diet quality indices is said to be the ultimate test of validity.[17] However, this depends on the goals of the index, with some diet quality indices developed to assess the relationship with health outcomes specifically, or more generally to determine adherence to published population based dietary guidelines. To validate dietary assessment tools a range of methods are used including comparing the outcomes of two different dietary assessment tools or comparing a dietary assessment tool to some other measure of dietary intake for example dietary biomarkers. The food frequency questionnaire used to calculate diet quality scores in this study was previously validated against three, four day weighed food records.[18,19]

These methods have now been applied to diet quality indices to examine the relationship to nutrients as well as health outcomes.[20-23] Therefore the aim of this study was to determine the accuracy of the TDS as a measurement tool of adherence to published dietary guidelines, using two different validation methods. Firstly, to compare TDS calculated from a FFQ against scores computed from the average of three, four-day weighed food records (WFRs) in the same population. Secondly, to compare the TDS calculated from a FFQ to a number of nutritional biomarkers as indicators for risk of developing chronic disease.

METHODS

The Blue Mountains Eye Study (BMES) is a population-based cohort study of vision and common eye diseases in residents aged 49 years or older living in a two-postcode region, west of Sydney, Australia. Full details of the study design and methods have been published previously.[24,25] BMES examinations were completed at baseline (BMES1, between 1992 and 1994), by 3,654 participants (82.4% of eligible people). At the first follow up (BMES 2a; 1997-1999) 2,335 (75.1%) survivors were examined along with an additional 1,174 participants recruited in 1999 to capture residents who had moved into the area or reached the

age of 49 (BMES2b). A total of 3,509 individuals were examined as part of BMES cross section 2, a combination of BMES2a and BMES2b. The sample population groups differed for each comparison method. For the comparison of dietary assessment tools (TDS-FFQ vs TDS-WFR) a sub sample of participants were recruited from BMES1 (Sample 1). Biomarker data was analysed from fasting blood samples collected during clinic visits for BMES cross section 2 (Sample 2) as described above. Ethics approval was granted by the Western Sydney Area Health Services Human Research Committee and the University of Sydney Human Research Ethics Committee. All participants provided written consent prior to enrolment.

TDS Validation study participants (Sample 1)

Sample 1 is a random sample of BMES1 subjects aged between 65 and 85 years (n=186) who were selected to complete three WFRs, each with a four-day duration in 1994. These WFRs were completed every four months over a one-year period to allow for seasonal variability, providing a total of 12 days of WFR. Of the 150 subjects who accepted the opportunity, 78 subjects successfully completed 12 days of WFRs (response rate=52%). All participants in the validation study completed the FFQ as part of the BMES1 cohort.

Food frequency questionnaire

The semi-quantitative FFQ included 145 items and was adapted for the Australian diet from an earlier Willett FFQ.[25] Participants used a nine-category frequency scale, ranging from never to four times a day, to indicate usual consumption of particular food items during the past year. FFQ validity was assessed in a previous study by comparing nutrients from the FFQ to the three 4-day WFRs (n=78).[18,19,25] Australian Tables of Food Composition were used to estimate dietary intakes and data were entered and analysed using a purpose built software analysis system with NUTTAB90 for BMES1 and NUTTAB95 for BMES cross section 2.

Total diet score

Details of the TDS have been published previously;[13] briefly, the TDS was modified from the Australian Health Eating Index (AHEI)[26] to measure total diet quality based on recommended foods outlined in the DGAA and the Australian Guide to Healthy Eating (AGHE).[10,27] Additional components from the US 2005 Dietary Guidelines Adherence Index (DGAI) were adapted and included in the TDS to better reflect the DGAA, as the DGAI addressed issues in the American population that were similar to those within the Australian population.[28]

The TDS was divided into ten components, and each component had a maximum score of 2 for those who met the recommendations with prorated scores between 0 and 2 for lower intakes. Component scores were summed providing a final score ranging between 0 and 20. The TDS measured both food intake from the five core food groups and consumption of optimal choice foods identified as providing greater dietary benefits, as recommended in the AGHE. Food intake components were based on adherence to AGHE recommendations for total intakes of vegetables, fruit, cereals and breads, meat including lean meats, fish, poultry and/or alternatives and dairy as well as low sodium, alcohol, sugar and extra foods intakes. Healthy choice components determined intakes of options with greater dietary benefits including serves of whole grain cereals, lean red meat, ratio of low or reduced fat milk to whole milk, low saturated fat intake and fish consumption. Details of the 10 individual components are provided in Table 1.

Cut points for scores were determined from published recommendations with the exception of fruits and vegetables. FFQ overestimation of fruit and vegetable intake was determined in this cohort by the validity study[25] and from our own analysis we found significant mean differences between the FFQ and WFRs of 161.8 g (SD 184.1) (equivalent to 2.1 serves) and 160.9 g (SD 228.8) (equivalent to 1.1 serves) for vegetable and fruit intake respectively. Therefore we replaced the AGHE's recommended two serves per day of fruit with three serves per day and the number of vegetables consumed per day from five serves to seven serves to allow for the overestimation. The AGHE recommended fruit and vegetable serves per day were used when calculating the WFRs' TDS scores. A full breakdown of the TDS scoring system has been previously published.[13]

The non-dietary AGHE recommendation for preventing weight gain was also included in the TDS score. Half the score was assigned to energy balance (the ratio of energy intake (EI) to energy expenditure (EE) and half the score to leisure time physical activity. A score of one for energy balance was allocated for ratios between 0.76 and 1.24, defined as the 95% confidence levels of agreement between EI and EE.[29] For each participant, energy expenditure was calculated from estimated basal metabolic rate (the Schofield equation[30]) and physical activity level. Physical activity levels were self-reported at the clinic visits using questions from the Australian National Heart Foundation Risk Factor Prevalence Surveys.[31] Walking, moderate or vigorous activities were scored as Metabolic Equivalents (METs) as described by Craig et al[32] and divided into tertiles with participants in the highest tertile for physical activity assigned a maximum one point score decreasing to a 0 score for those in the lowest tertile of physical activity.

Laboratory analyses (Sample 2)

Fasting blood samples from Sample 2 were drawn and sent, on the same day, to Westmead Hospital clinical pathology laboratory, Sydney, Australia for analysis and assessment. Serum vitamin B12 and serum folate assays were performed using the competitive-binding assay method, using a Beckman-Access analyser (Beckman Coulter, Gladesville, Sydney, Australia). For homocysteine from blood, the fluorescent polarization immunoassay method was conducted on an IMx analyzer (Abbott Laboratories, Abbot Park, Illinois, USA). Serum lipid samples (total cholesterol, HDL cholesterol and triglycerides) were measured on a Reflotron reflectance photometric analyzer (Boehringer Mannheim Diagnostics). Serum LDL cholesterol levels were calculated using the Friedewald equation (LDL cholesterol=total cholesterol-HDL cholesterol- (triglycerides/5)).[33]

Statistical analysis

Descriptive analyses of subjects were calculated along with mean TDS from both the FFQ and the WFR for each subject. Paired t tests were conducted to determine differences in TDS between the two dietary assessment methods. Three methods were used to assess the reliability of the TDS: Pearson product moment correlations, Bland-Altman limits of agreement[34] and weighted kappa scores.[35] The data were divided into quartiles for both FFQ and WFR TDS respectively to determine the degree of classification agreement between quartiles. Gross misclassification was identified when the TDS from one assessment method was classified in the lowest quartile and the other TDS classified into the highest score. Results were considered statistically significant at the $p<0.05$ level. Tests for normality of the total TDS data were conducted using the Shapiro Wilk test and the data were found to be normally distributed.

For analysis of plasma/serum concentrations, each biomarker was considered an individual dependent variable with quartiles of TDS, the independent variable. Pearson correlation coefficients (r) and partial correlations were calculated to assess the linear relationship between TDS and biomarkers separately. Partial correlations were adjusted for age, gender, BMI, smoking status and for dietary supplement intake of serum vitamin B12 and folate, respectively. The biomarkers were found to be skewed following tests of normality that were significant, therefore each biomarker variable was log transformed for analysis to improve normality. Multiple linear regression models were created to assess potential confounding variables including gender, age, education level (high school or less vs education after high school), BMI (kg/m^2), smoking status (non smoker vs smoker), energy intake (kJ) and, for

serum vitamin B12 and serum folate, respective dietary supplement use. The potential confounding variables were selected a priori from previous findings in the literature. For consistency, the same covariates were adjusted for in each biomarker and included those that were significant for at least four of the biomarkers ($p<0.05$). The covariates in the final model included gender, age, BMI and smoking status with vitamin B12 and folate dietary supplement use additionally included for serum vitamin B12 and serum folate biomarkers, respectively. Trend analysis was conducted on each biomarker with TDS as a continuous variable.

Analyses were performed using IBM SPSS Statistics for Windows (Version 19.0, 2010, Armonk, NY, USA) except for weighted kappa scores, which were calculated using SAS statistical software (version 9.2; SAS Institute, Cary, NC, USA).

RESULTS

Comparison of TDS from food frequency questionnaire and weighed food records

The mean age of the 75 participants included in the validation study (sample 2) is shown in Table 2. Details of the validation study have been described in detail previously.[18,19,25] Two subjects were excluded from the analysis due to large differences in Total Diet Scores calculated from FFQs and WFRs (>5 TDS points) and one other subject was excluded because they had no physical activity data available.

No significant differences were found between the means of the FFQ TDS and WFR TDS although the mean score was higher in the FFQ TDS (9.66 vs 9.43, respectively, $p=0.63$). The Pearson correlation results given in Table 12 show the strength of the relationship between the two methods was good (0.63, $p<0.001$). We used a Bland-Altman plot to assess agreement visually (Figure 1). The regression analysis showed there was no significant linear trend, indicating no systematic bias between the scores of the two assessment methods ($p=0.38$). The proportion of subjects correctly classified to within one quartile of TDS was 88% (Table 2). A higher proportion of men were correctly classified within one quartile than women and no participants were grossly misclassified. The weighted kappa value (0.39) showed fair to moderate agreement overall, but the weighted kappa score for women was lower than men indicating fair agreement (0.32 vs 0.44).

TDS and nutritional biomarkers

Descriptive details, by TDS quartile, of participants included in the nutritional biomarker analysis are given in Table 3. There was no significant difference in mean age between

participants with the highest and lowest quartiles of TDS. The proportion of women increased through the quartiles of TDS from lowest to highest diet quality. The opposite effect was found in current smokers, with the proportion decreasing significantly from lowest quartile of TDS to highest quartile of TDS.

Pearson Correlation coefficients and partial correlations are given in Table 4. TDS was positively correlated with serum vitamin B12 and folate and negatively correlated with homocysteine and triglycerides. Crude HDL cholesterol concentrations were positively correlated with TDS although the partial correlation was negative (-0.159, $p<0.004$). For most other nutritional biomarkers, after adjusting for potential confounders the partial correlations were attenuated.

The TDS was divided into quartiles and those with the highest diet quality (Q4) were compared to those with the lowest diet quality (Q1) and found to be significantly different in the expected direction for serum vitamin B12, folate, homocysteine and total cholesterol as shown in Table5. Higher TDS scores were significantly associated with higher serum vitamin B12 and serum folate as well as lower levels of homocysteine, total cholesterol and, unexpectedly, HDL cholesterol after adjusting for gender, age, BMI and smoking status (Table 5).

DISCUSSION

The TDS was developed to assess adherence to the Australian dietary guidelines in an older population and our findings indicate that the TDS reflects compliance with published dietary guidelines with some accuracy. The moderate correlations between the two dietary assessment methods indicated that the FFQ estimates diet quality similar to weighed food records. In addition, our findings, similar to others, suggest individuals can be ranked with some accuracy in terms of diet quality even though FFQs are not as reliable a tool for assessing food intakes as weighed food records.[17]

The FFQ used to calculate diet quality score has previously been validated against three, four day food records; however, the TDS also incorporates energy balance and physical activity levels within the scores.[18,19,25] The analysis was rerun removing the non dietary component from the TDS for both dietary assessment methods, and the mean differences in TDS scores from FFQ to WFR were similar when compared (0.23, $p=0.63$ including all components and 0.19, $p=0.37$ excluding preventing weight gain component). The small differences between the TDS scores including and excluding the 'preventing weight gain' (PWG) component could describe the differences in physical activity levels in this population

and overall food intakes. It should be noted that the overall score for the non-dietary component would differ between the two methods because of the difference in calculated energy balance although the physical activity data were the same for both FFQ and WFR.

Our finding that the FFQ overestimated TDS compared to the WFR but not to a significant level, was similar to one other study of Belgian preschoolers using the Bland-Altman method.[36]

Overestimation of fruit and vegetable intake in self-reported FFQs is commonly reported and this was also found to be true in our cohort.[25] We accounted for the overestimation by increasing the number of recommended serves of fruit and vegetable from 2 to 3 and 5 to 7 respectively to achieve a maximum Total Diet Score. The small difference between the fruit and vegetable component TDS scores from the two methods was 0.06 out of a maximum 2 points (3%) and provides further justification for the increased number of serves used.

The component scores from the FFQ and WFR were examined (data not shown) to determine how the individual components contributed to the overall TDS. Alcohol intake scored the highest mean individual component scores (1.63 out of 2 and 1.71 out of 2 respectively), suggesting that this population consumed alcohol within the recommended guidelines. Conversely, the sugar intake component had the lowest component scores (0.41 out of 2 and 0.49 respectively) suggesting intakes of sugar above the DGAA's recommended intake. The percentage of energy from sugar was calculated from all sugar consumed in the diet and did not distinguish between naturally occurring and added sugars, for example, sugar derived from fruit was included which could reflect higher intakes of fruit. However the Australian dietary guidelines recommended moderate intakes of sugar and food with added sugar to limit the loss of nutrient dense foods in the diet.[10]

The TDS was also compared to dietary biomarkers. Correlations found between the TDS and nutritional biomarkers suggested a small effect size ($r<0.20$).[37] However, these findings were consistent with previous studies that have assessed diet quality against dietary biomarkers.[3,21,22,38] Serum levels of vitamin B12, folate and homocysteine had greater correlations to the TDS than lipid biomarkers. One explanation may be that lipids were not an accurate measure of dietary fat intake because serum cholesterol levels could have been affected by a range of nutrients as well as type of fat intake.[39] However, in the BMES survivor cohort it was found that serum lipid profiles improved with decreased saturated fatty acid intake and increased n-3 fatty acids and fish intake over a ten year period independent of lipid lowering medication use.[40] Plasma cholesterol levels may also be affected by individual genetic variation and degree of disease more so than dietary fat intake. It has been suggested

that diseases, such as diabetes, infections and inflammation may affect serum cholesterol concentrations as well as lower lipid levels following an acute myocardial infarction.[39] For this older adult cohort it may be particularly relevant as many participants reported a diagnosis of at least one health condition.

The finding that HDL cholesterol concentrations decreased with increasing diet quality was interesting. Similar results have been reported previously but the reason for these findings is not clear. One explanation could be the lack of adjustment or exclusion of participants with chronic diseases or those taking medications.[20,21] In addition, higher HDL cholesterol concentrations were reported in participants consuming a western style diet described as high in red and processed meat and 'discretionary foods".[41]

The TDS was developed to assess adherence to the 2003 Australian Dietary Guidelines, these dietary guidelines were updated in 2013. The 2013 Australian Dietary Guidelines evolved from the 2003 DGAA with the main messages remaining similar to the earlier version but based on stronger evidence.[42] In the updated dietary guidelines more emphasis has been placed on achieving and maintaining a healthy weight with a new guideline that "Older people should eat nutritious foods and keep physically active to help maintain muscle strength and a healthy weight".[42] This is addressed in the TDS by the inclusion of a component score for preventing weight gain that is scored on energy balance and level of physical activity. However, the scoring algorithm does require some adaptation to reflect changes to recommended serve sizes eg. reduce the current scoring for lean meat and meat alternatives to the new recommendation that men and women aged 51 and over consume 2.5 serves and 2 serves, respectively. Updating the TDS to accurately reflect the current dietary guidelines would provide an opportunity to also adapt the tool for use in other age groups from the Australian population.

The aim of the DGAA was to improve the community's health and well-being as well as reduce the risk of diet-related disease.[10] In Australians aged 51 and over just over half of reported folate intake was derived from cereal and cereal product whilst the primary source of vitamin B12 was meat and poultry products and dishes followed by milk products and dishes.[43] The significant trends for increasing Vitamin B12 and serum folate levels along with decreasing homocysteine concentrations with increasing TDS suggested these were reflected by the TDS.[44] Total cholesterol and LDL-cholesterol concentrations followed a similar pattern, although the trend for serum LDL cholesterol was not significant. Lipid concentrations were higher in all quartiles than the highest quartile for diet quality with a significant difference found between quartile 2 and quartile 4. It is suggested that this tool

may be useful for measuring diet quality and risk of developing chronic diseases in epidemiological or population studies as hyperhomocysteinaemia has been identified as a risk factor for coronary heart disease mortality in observational studies.[45,46]

When discussing dietary assessment, the limitations must be considered. All dietary assessment methods suffer from different degrees of error; however dietary intake as measured by FFQs is often validated by comparing intakes to weighed food records. The latter assessment method is considered one of the more reliable dietary assessment methods and has the lowest correlated errors when compared to food frequency questionnaires.[47] These issues have been addressed previously as the FFQ used in this study has similar degrees of correlation when compared to the weighed food records.[25] To determine the relative validity of the TDS additional methods were applied including Bland-Altman plots, cross-classification and weighted kappa scores, which allowed for greater understanding of the strengths and weaknesses of the TDS. A further limitation was missing food items from the FFQ that were included in participant's WFRs. Foods that were not included in both dietary assessment methods were excluded from the analysis, for example water, and herbs and spices. A further possible limitation was the sample size (n=75), however in a review of FFQ validation studies, the sample size did not impact on the study results.[48] In addition, older age in the validation study was intentional because age-related diseases were the primary outcomes in this older cohort that are uncommon in younger people.[25]

Conclusion

Overall, we found good correlation and agreement between the TDS scores when calculated from the two dietary assessment methods; these findings in combination with the association of the TDS with biomarker concentration suggest that this tool could be useful for determining diet quality in terms of adherence to the Australian Dietary Guidelines at the population level. Further validation of the TDS would be beneficial, for example comparing scores against other diet quality indices. There is also potential for the TDS to be adapted for use in other Australian age group populations but this, again, would require further validation.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1. Slattery ML. Defining dietary consumption: is the sum greater than its parts? Am J Clin Nutr. 2008;88:14-15.
2. Hu FB, Rimm E, Smith-Warner SA, Feskanich D, Stampfer MJ, Ascherio A, Sampson L, Willett WC. Reproducibility and validity of dietary patterns assessed with a food-frequency questionnaire. Am J Clin Nutr. 1999;69:243-9.
3. Hann CS, Rock CL, King I, Drewnowski A. Validation of the Healthy Eating Index with use of plasma biomarkers in a clinical sample of women. Am J Clin Nutr. 2001;74:479-86.
4. Wirt A, Collins CE. Diet quality - what is it and does it matter? Public Health Nutr. 2009;12:2473-92. doi: 10.1017/S136898000900531X.
5. McCullough M, Feskanich D, Rimm EB, Giovannucci E, Ascherio A, Variyam J, Spiegelman D, Stampfer M, Willett WC. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in men. Am J Clin Nutr. 2000;72:1223-31.
6. McCullough M, Feskanich D, Stampfer M, Rosner B, Hu FB, Hunter D, Variyam J, Colditz G, Willett WC. Adherence to the Dietary Guidelines for Americans and risk of major chronic disease in women. Am J Clin Nutr. 2000;72:1214-22.
7. Fogli-Cawley J, Dwyer J, Saltzman E, McCullough M, Troy L, Meigs J, Jacques PF. The 2005 Dietary Guidelines for Americans and risk of the metabolic syndrome. Am J Clin Nutr. 2007;86:1193-201.
8. Imamura F, Jacques PF, Herrington DM, Dallal GE, Lichtenstein AH. Adherence to 2005 Dietary Guidelines for Americans is associated with a reduced progression of coronary artery atherosclerosis in women with established coronary artery disease. Am J Clin Nutr. 2009;90:193-201. doi: 10.3945/ajcn.2009.27576.
9. Fransen HP, Ocké MC. Indices of diet quality. Curr Opin Clin Nutr Metab. 2008;11:559-65. doi: 10.1097/MCO.0b013e32830a49db.
10. National Health and Medical Research Council. Dietary Guidelines for Australian Adults. Canberra: National Health & Medical Research Council; 2003.
11. McNaughton SA, Ball K, Crawford D, Mishra G. An index of diet and eating patterns is a valid measure of diet quality in an Australian population. J Nutr. 2008;138:86-93.
12. Zarrin R, Ibiebele TI, Marks GC. Development and validity assessment of a diet quality index for Australians. Asia Pac J Clin Nutr. 2013;22:177-87. doi: 10.6133/apjcn.2013.22.2.15.

13. Russell J, Flood V, Rochtchina E, Gopinath B, Allman-Farinelli M, Bauman A, Mitchell P. Adherence to dietary guidelines and 15-year risk of all-cause mortality. Br J Nutr. 2013;109:547-55. doi: 10.1017/S0007114512001377.
14. Gopinath B, Flood VM, Wang JJ, Rochtchina E, Wong TY, Mitchell P. Is quality of diet associated with the microvasculature? An analysis of diet quality and retinal vascular calibre in older adults. Br J Nutr. 2013;110:739-46. doi: doi:10.1017/S0007114512005491.
15. Gopinath B, Harris DC, Flood VM, Burlutsky G, Mitchell P. A better diet quality is associated with a reduced likelihood of CKD in older adults. Nutr Metab Cardiovas. 2013;23:937-43. doi: 10.1016/j.numecd.2012.07.003.
16. Hong T, Flood V, Rochtchina E, Mitchell P, Russell J, Wang JJ. Adherence to dietary guidelines and the 10-year cumulative incidence of visual impairment: The Blue Mountains Eye Study. Am J Ophthalmol. 2014;158:302-08. doi: 10.1016/j.ajo.2014.05.011.
17. Newby PK, Hu FB, Rimm EB, Smith-Warner SA, Feskanich D, Sampson L, Willett WC. Reproducibility and validity of the Diet Quality Index Revised as assessed by use of a food-frequency questionnaire. Am J Clin Nutr. 2003;78:941-9. doi:
18. Flood VM, Smith WT, Webb K, Mitchell P. Issues in assessing the validity of nutrient data obtained from a food-frequency questionnaire: folate and vitamin B12 examples. Public Health Nutr. 2004;7:751-56. doi: 10.1079/PHN2004604.
19. Barclay AW, Flood VM, Brand-Miller JC, Mitchell P. Validity of carbohydrate, glycaemic index and glycaemic load data obtained using a semi-quantitative food-frequency questionnaire. Public Health Nutr. 2008;11:573-80. doi: 10.1017/s1368980007001103.
20. Kant AK, Graubard BI. A comparison of three dietary pattern indexes for predicting biomarkers of diet and disease. J Am Coll Nutr. 2005;24:294-303. doi: 10.1080/07315724.2005.10719477.
21. Weinstein SJ, Vogt TM, Gerrior SA. Healthy Eating Index scores are associated with blood nutrient concentrations in the third National Health and Nutrition Examination Survey. J Am Diet Assoc. 2004;104:576-84. doi: 10.1016/j.jada.2004.01.005.
22. Bach-Faig A, Geleva D, Carrasco JL, Ribas-Barba L, Serra-Majem L. Evaluating associations between Mediterranean diet adherence indexes and biomarkers of diet and disease. Public Health Nutr. 2006;9:1110-7. doi: 10.1017/S1368980007668499.
23. Freisling H, Elmadfa I, Schuh W, Wagner KH. Development and validation of a food frequency index using nutritional biomarkers in a sample of middle-aged and older adults. J Hum Nutr Diet. 2009;22:29-39. doi: 10.1111/j.1365-277X.2008.00916.x.
24. Mitchell P, Smith W, Webb K, Leeder S. Prevalence of age-related maculopathy in Australia: The Blue Mountains Eye Study. Ophthalmology. 1995;102:1450-60.
25. Smith W, Mitchell P, Reay EE, Webb K, Harvey PWJ. Validity and reproducibility of a self-administered food frequency questionnaire in older people. Aust N Z J Public Health. 1998;22:456-63.
26. Australian Institute of Health and Welfare. Australian diet quality index project. Canberra: Australian Institute of Health and Welfare;2007. AIHW cat no PHE 85.

27.Smith A, Kellett E, Schmerlaib Y. The Australian Guide to Healthy Eating. Canberra: Commonwealth of Australia; 1998.

28.Fogli-Cawley J, Dwyer J, Saltzman E, McCullough M, Troy L, Jacques PF. The 2005 Dietary Guidelines for Americans Adherence Index: development and application. J Nutr. 2006;136:2908-15.

29.Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA, Prentice AM. Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording. Eur J Clin Nutr. 1991;45:569-81.

30.Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr. 1985;39 Suppl 1:5-41.

31.Risk Factor Prevalence Study Management Committee. Risk Factor Prevalence Study: Survey No 3 1989. Canberra: National Heart Foundation of Australia and Australian Institute of Health; 1990.

32.Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports. 2003;35:1381-95. doi: 10.1249/01.mss.0000078924.61453.fb.

33.Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem. 1972;18:499-502.

34.Bland JM, Altman DG. Statistical methods for assessing agreement between 2 methods of clinical measurement Lancet. 1986;1:307-10.

35.Cohen J. Weighted Kappa - nominal scale agreement with provision for scaled disagreement or partial credit Psychol Bull. 1968;70:213-20. doi: 10.1037/h0026256.

36.Huybrechts I, Vereecken C, De Bacquer D, Vandevijvere S, Van Oyen H, Maes L, et al. Reproducibility and validity of a diet quality index for children assessed using a FFQ. Br J Nutr. 2010;104:135-44. doi: 10.1017/s0007114510000231.

37.Cohen J. A power primer. Psychol Bull. 1992;112:155-59.

38.Toft U, Kristoffersen LH, Lau C, Borch-Johnsen K, Jorgensen T. The Dietary Quality Score: validation and association with cardiovascular risk factors: the Inter99 study. Eur J Clin Nutr. 2007;61:270-8. doi: 10.1038/sj.ejcn.1602503

39.Bates CJ, Thurnham DI, Bingham S, Margetts B, Nelson M. Biochemical markers of nutrient intake. In: Margetts B, Nelson M, editors. Design concepts in nutritional epidemiology. Oxford: Oxford University Press; 1997. pp. 170-240.

40.Buyken AE, Flood V, Rochtchina E, Nestel P, Brand-Miller J, Mitchell P. Modifications in dietary fat quality are associated with changes in serum lipids of older adults independently of lipid medication. J Nutr. 2010;140:88-94. doi: 10.3945/jn.109.110486.

41.Fung TT, Rimm EB, Spiegelman D, Rifai N, Tofler GH, Willett WC, Hu FB. Association between dietary patterns and plasma biomarkers of obesity and cardiovascular disease risk. Am J Clin Nutr. 2001;73:61-67.

42.National Health and Medical Research Council. Australian Dietary Guidelines. Canberra: Department of Health and Ageing; 2013.

43. Australian Bureau of Statistics. Australian Health Survey: Nutrition First Results – Food and Nutrients, 2011-12 Cat. 4364. Canberra, ACT: Australian Bureau of Statistics; 2014.
44. National Health and Medical Research Council, Department of Health and Ageing. Nutrient Reference Values for Australia and New Zealand. Canberra: NHMRC; 2006.
45. Gopinath B, Flood VM, Rochtchina E, Thiagalingam A, Mitchell P. Serum homocysteine and folate but not vitamin B-12 are predictors of CHD mortality in older adults. Eur J Prev Cardiol. 2012;19:1420-29. doi: 10.1177/1741826711424568.
46. Humphrey LL, Fu RW, Rogers K, Freeman M, Helfand M. Homocysteine level and coronary heart disease incidence: A systematic review and meta-analysis. Mayo Clin Proc. 2008;83:1203-12. doi: 10.4065/83.11.1203.
47. Willett WC. Nutritional Epidemiology. New York: Oxford University Press; 1998.
48. Cade J, Burley V, Warm D, Thompson R, Margetts BM. Food-frequency questionnaires: a review of their design, validation and utilisation. Nutr Res Rev. 2004;17:5-22. doi: 10.1079/NRR200370.

Table 1. Individual components of the Total Diet Score (TDS) based on Australian Dietary Guidelines[10] and the Australian Guide to Healthy Eating[27]

Dietary Guideline / Component	TDS Component Description	Score (Range)	Total Score
1. Eat plenty of vegetables, legumes and fruit	Total vegetable serves/day	0-0.5	
	Vegetable variety score/day	0-0.5	
	Total fruit serves/day	0-1	2
2. Eat plenty of cereals, preferably wholegrain/meal	Total cereals serves/day	0-1	
	Wholegrain cereal serves/day	0-1	2
3. Include lean meats, fish, poultry and/ or alternatives	Meat/alternative/day	0-1.5	
	Lean red meat / week (i.e. > 0.428 /day)	0-0.5	2
4. Include milk, yoghurts, cheese and/or alternatives	Total dairy serves/day	0-1.5	
	Ratio of skim/low fat (S/LF) intake to whole milk intake	0-0.5	2
5. Limit saturated fat and moderate total fat intake	Percentage of energy from saturated fat	0-1	
	Fish serves/week	0-1	2
6. Choose foods low in salt	Sodium intake/day	0-2	2
7. Limit alcohol intake if you choose to drink	Alcohol intake/day	0-2	2
8. Consume only moderate amounts of sugars and foods with added sugars	Percentage of energy from sugar	0-2	2
9. Extra foods, not essential to provide nutrients and may be high in salt, fat or sugar	Extra food serves/day	0-2	2
10. Prevent weight gain: be physically active and eat according to energy needs	Ratio of energy intake to energy expenditure	0-1	
	Physical activity (METs)	0-1	2
Total score			20

Table 2. Analysis of Total Diet Score calculated from two dietary assessment methods (BMES1)

	Male n=35	Female n=40	Total n=75
Mean age (yrs)	70.7	69.7	70.1
Total Diet score, mean (SD)			
FFQ	9.2 (2.2)	9.8 (2.4)	9.7 (2.3)
WFR	9.6 (2.4)	9.2 (1.9)	9.4 (2.1)
Mean difference (FFQ TDS – WFR TDS)	-0.43 (p=0.13)	0.58 (p=0.08)	0.23 (p=0.63)
LOA[†]	2.83, -3.69	4.48, -3.52	3.95, -3.74
Pearson Correlation	0.75[*]	0.54*	0.63*
Weighted Kappa	0.44	0.32	0.39
Percentage correctly classified into same quartile	42.9%	32.5%	37.3%
Percentage correctly classified within 1 quartile	88.6%	87.5%	88.0%
Percentage grossly misclassified	0	0	0

[†]LOA Limit of agreement.
[*] p<0.0001 for difference between TDS-FFQ and TDS-WFR.

Table 3. Characteristics of BMES2 Cross Section 2 participants included in biomarker analysis (n=2486)

	Quartiles of TDS			
	Q1 n=619	Q2 n=623	Q3 n=616	Q4 n=627
Age (mean, yrs)	66.5 (9.51)	66.4 (9.45)	66.5 (8.51)	66.2 (8.81)
BMI, mean (SD)	27.8 (4.82)	27.3 (4.60)	27.8 (4.80)	27.3 (4.60)
Energy intake (mean KJs, SD)	8603 (2791)	8761 (2670)	8376 (2328)	8379 (1843)
Gender				
Female (%)	47.0	53.1	59.6	57.3[**]
Current Smoker (%)	13.2	9.8	8.5	4.8[**]
Takes folate supplement (%)	9.9	15.7	11.9	15.6[*]
Takes vitamin B12 supplement (%)	13.1	18.9	15.9	21.7[*]

p value: [*]<0.01 [**]<0.0001 Significant difference between quartile 1 (lowest diet quality) and quintile 4 (highest diet quality).

Table 4. Pearson Correlations(r) of Total Diet Score with dietary biomarkers (n=2486)

Biomarker	Total Diet Score	
	Correlations	Partial Correlations[†]
Vitamin B12 (pmol/L)	0.109[*]	0.088[*]
Serum folate (mmol/L)	0.139[*]	0.106[*]
Homocysteine (µmol/L)	-0.183[*]	-0.159[*]
Total cholesterol (mmol/L)	-0.030	-0.068
HDL Cholesterol (mmol/L)	0.022	-0.059
LDL Cholesterol (mmol/L)	-0.029	-0.038
Triglycerides (mmol/L)	-0.047[*]	-0.033

[†]Partial correlations adjusted for Age, Gender, BMI, Smoking status and respective supplement use for serum vitamin B12 and serum folate.
p value < 0.05.

Table 5. Associations between nutritional biomarkers and quartiles of Total Diet Score (n = 2486)

Biomarker	Adjusted Mean† concentrations across quartiles of TDS				
	Q1	Q2	Q3	Q4	*p* for trend‡
Vitamin B12 (pmol/L)	243**	252	253	268	<0.0001
Serum folate (nmol/L)	15.5***	16.1*	16.4	17.5	<0.0001
Homocysteine (µmol/L)	12.3***	11.3	11.2	10.8	<0.0001
Cholesterol (mmol/L)	5.81*	5.82*	5.69	5.62	0.001
HDL Cholesterol (mmol/L)	1.44	1.42	1.41	1.39	0.004
LDL Cholesterol (mmol/L)	3.95	4.01*	3.89	3.85	0.06
Triglycerides (mmol/L)	1.41	1.37	1.35	1.34	0.11

†Least square mean scores adjusted for gender, age, BMI and smoking status. Vitamin B12 and folate biomarkers were additionally adjusted for respective dietary supplement intake. Scores log transformed for analysis and exponentiated for presentation.
‡*p* for trend calculated with TDS as a continuous variable.
*<0.05; ** <0.001; ***<0.0001; *p* values for significant difference in TDS from Q4 (highest diet quality).

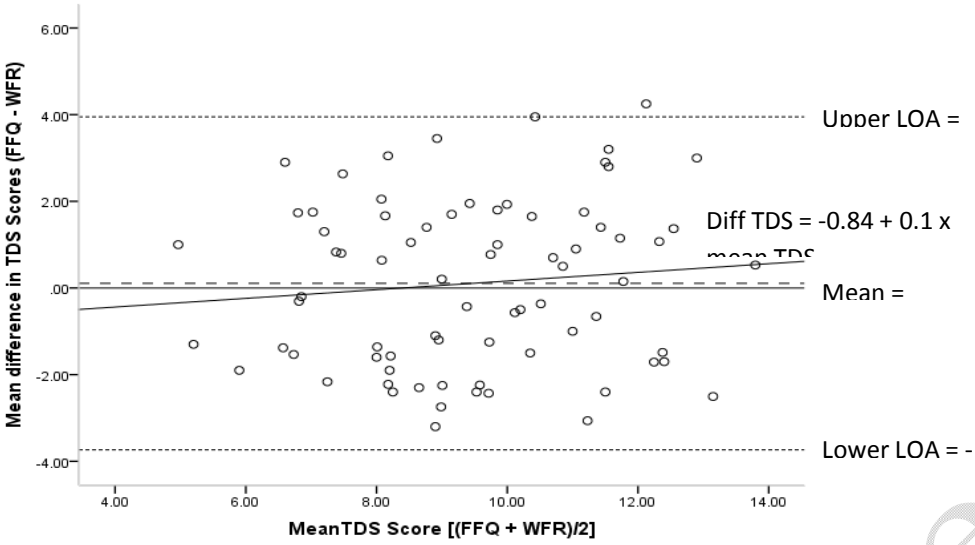

Figure 1. Bland–Altman method of assessing agreement between TDS scores calculated from FFQs and WFRs (n=75) FFQ=food frequency questionnaire, WFR=4-day weight food record; LOA=limit of agreement.