Fruit, vegetables and discretionary food intake in Australian adults: Past trends and predicted progress towards population preventive health targets for 2030

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Abstract

Objective: In Australia, *'improving access to and the consumption of a healthy diet'* is a focus in the National Preventive Health Strategy. The objective of this paper is to describe the past trends and future projections of population intakes against the Strategy's targets of increasing fruit consumption to 2 servings per day; increasing vegetables to 5 servings; and reducing discretionary foods to <20% of total energy by 2030.

Methods: Self-reported intake data were available from an online survey of 275,170 Australian adults collected between 2015 and 2023. Dietary intake was modelled for sex and four age groups and forecasted towards 2030 using gamma-generalised linear models.

Results: By 2030, fruit intake is predicted to decrease by 9.7%, discretionary food intake predicted to increase by 18.3%, and vegetable intake predicted to remain stable (but well short of national targets). Differences by sex and age group included an increase in fruit predicted for 18-30 year-olds, and a decrease in vegetables for females but an increase for males.

Conclusions: Without significant intervention, it will be difficult to meet Australia's preventive health dietary targets.

Implications for Public Health: Continuous monitoring will be important to inform targeted interventions to improve diet quality and health outcomes.

Key words: vegetables, fruit, discretionary food, modeling, predicted intake

Background

An unhealthy diet is an important risk factor for obesity and other chronic diseases globally.[1] The Global Burden of Diseases, Injuries, and Risk Factors Study 2017 reported dietary risks were responsible for 11 million deaths globally, with cardiovascular disease, cancer and type 2 diabetes the leading causes of dietary-related deaths across 195 countries analysed. The dietary factors impacting most on health outcomes globally were high intake of sodium, low intake of wholegrains and low intake of fruit.[2] In Australia, it is estimated that dietary risks were responsible for 5.4% of the burden of disease (in 2018), and more specifically, diets low in legumes, wholegrains, fruit, nuts, seeds and vegetables, and diets high in sodium and red meat were the greatest dietary risks.[3] These data highlight the critical need to improve dietary habits for better population health outcomes.

Australia, like many countries around the world, has food-based dietary guidelines providing recommendations to improve health and wellbeing.[4] For example, in Australia, 2 servings of fruit, 5 servings of vegetables and no more than 3 servings of discretionary foods (those high in saturated fat, salt and sugar) are recommended each day for good health. However, about half the adult population consumes enough fruit, less than 5% meet the recommendations for vegetables, and on average we consume twice the recommended amounts of discretionary foods each day.[5,6] Changing population dietary habits has proven challenging, but the beneficial health outcomes associated with behaviour changes are significant. A systematic review and meta-analysis reported the risk of all-cause mortality decreased by about 9% with increasing fruit to 2 servings and about 11% with increasing vegetables to 5 servings per day.[7] An Australian modelling study reported that a reduction in discretionary food intake in the order of one serving per week (replaced with a healthy

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alternative) would result in a positive impact on weight and health-adjusted life years and save up to AUD$793 million in lifetime healthcare costs.[8] Given the health, economic and societal benefits associated with consuming a healthier diet, governments around the world are focused on preventive health and investing in initiatives to improve eating habits.

In Australia, the National Preventive Health Strategy (2021-2030) has *'improving access to and the consumption of a healthy diet'* as one of its seven focus areas.[9] Five objective targets around healthy diets are described: (1) maintain or increase fruit consumption to an average of 2 serves per day; (2) increase vegetable consumption to an average of 5 servings per day; (3) reduce the proportion of total energy intake from discretionary foods from >30% to <20%; (4) reduce sodium intake by at least 30%; and (5) increase the proportion of people not exceeding the recommended intake of free sugar by 2030. Current consumption patterns in Australia would suggest that these targets are ambitious, and significant action will be needed to change the status quo within this timeframe.

Predictive modelling is a rapidly developing area in public health and was used widely for public health benefit during the COVID pandemic.[10] Using predictive modelling to understand trends in dietary behaviour is less well established; however, would be useful to inform policy decisions and guide interventions. Therefore, this paper will use a generalised linear modelling approach to provide projections of dietary intake out to 2030. This outlook will be useful to facilitate government planning, intervention, and policy development to support the achievement of Australia's National Preventive Health Strategy targets. The objectives of this paper were to describe the past trends (2015 to 2023) and future projections (through to 2030) in fruit and vegetable intake, and discretionary foods intake in Australia; and to identify age and sex subgroups of the population at greater risk of not meeting these targets.

Methods

This study used data from a cross-sectional online survey of Australian adults. The reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology–Nutritional Epidemiology (STROBE-Nut)[11] guidelines (Supplementary Material Table S4).

Data collection

Self-reported dietary intake data were collected using the CSIRO Healthy Diet Score survey. The development and validation of the short food questions used in this survey have been described previously.[12] Briefly, the CSIRO Healthy Diet Score survey is designed to calculate a Dietary Guideline Index score[13,14] assessing compliance with the Australian Dietary Guidelines. The ability of the survey to assess overall diet quality has undergone validation in a sample of Australian adults.[12,15] When compared to estimates from three 24-hour recalls, the reported serves per day on the online survey was within one-third of a serve for the food groups included in this analysis.[15] The survey is a series of 38 short questions asking individuals to report their usual intake of core (fruit, vegetables, grains, meat and alternatives, and dairy and alternatives) and discretionary (e.g. cakes and biscuits, chocolate and confectionary, takeaway foods, savoury pies and pastries, sugar-sweetened beverages and alcohol) foods and beverages. Individuals are asked to think about their usual intake and report their frequency of consumption as daily, weekly or monthly, and portion consumed in multiples of standard serving sizes (serves).[16] This analysis used questions relating to fruit (1 item), vegetables (3 items) and discretionary foods and beverages (11 items). Daily intake (in serves per day) was calculated using the reported frequency (daily, weekly, monthly, never) and reported serves.

The survey also includes questions covering demographic characteristics of sex, age, and Australian state of residence, as well as self-reported height and weight.

The CSIRO Healthy Diet Score survey was launched on the 21 May 2015 and is freely available online (https://www.csiro.au/en/research/health-medical/diets/CSIRO-Healthy-Diet-Score). The survey sits on a live website, meaning data collection is continuous and ongoing. Media announcements have been conducted sporadically over the years since launch. These announcements have received national television, print and radio coverage across a range of free to air stations. These announcements were a way to draw individuals to the website to complete the survey; otherwise, individuals can find the website on their own, and if they are at least 18 years of age can complete the survey of their own volition. This paper uses data collected from individuals who completed the survey from the date of launch through to 31 December 2023.

Data cleaning

During the specified data collection period, the survey had been commenced 345,762 times. Using a standard process of data cleaning,[6] duplicate surveys were removed using an ID variable and taking the first survey attempt from each individual. In addition, partially completed surveys and outliers were removed based on extreme age (less than 18 years and greater than 100 years), body mass index (less than 13 and greater than 97), height (less than 1 m and greater than 3 m), and weight (less than 13 kg and greater than 250 kg). This left 275,170 individuals for analysis. Table 1 provides summary statistics for the sample over time by demographic characteristics.

The majority of the sample were female (73.3%), with a relatively even distribution across the 18–30, 31–50, 51–70 year age groups (30.5%, 33.6%, 31.8%). However, the oldest age group of 71 years and over was under-represented relative to the Australian population (4.1% *vs.* 14.3%[17]). The nature of recruitment resulted in a sample that was under-representative of males and older adults relative to the broader Australian population,[17] therefore survey data were weighted by sex and age group.

Statistical analysis

Past dietary intake (fruit, vegetables and discretionary foods) was modelled using a gamma hurdle generalised linear regression model (GLM).[18] The gamma hurdle GLM predicts the likelihood an individual will report more than zero serves and the expected number of dietary servings of an individual conditional on that individual reporting more than zero servings. The results for the hurdle model (those reporting zero serves) are reported in the Supplementary Material (Figs. S2–S5). In the gamma GLM, expected dietary servings were predicted using age, sex, year since 2015 and state of residence, as well as interactions between year since 2015 and age and sex. Population-level dietary guidance in Australia is provided by age and sex; therefore, these subgroups were the focus in the presentation of results. Once the

Table 1: Summary statistics for the sample over time. Dietary intake is presented in mean (sd) serves per day for individuals who reported more than zero serves per day. All other variables are presented as count (percentage) over time.

		2015	2016	2017	2018	2019	2020	2021	2022	2023
Servings	Fruit	1.50 (1.27)	1.48 (1.35)	1.46 (1.37)	1.43 (1.34)	1.48 (1.44)	1.44 (1.17)	1.43 (1.22)	1.38 (1.16)	1.42 (1.19)
	Vegetables	3.56 (2.97)	3.65 (3.03)	3.71 (3.23)	3.60 (3.14)	3.56 (3.29)	3.70 (2.92)	3.71 (3.22)	3.64 (2.97)	3.59 (2.91)
	Discretionary foods and beverages	3.60 (4.33)	3.77 (4.26)	4.00 (5.49)	4.06 (6.82)	4.12 (7.46)	3.82 (5.16)	4.31 (8.49)	4.34 (7.52)	4.25 (5.09)
Sex	Male	18961 (27.8)	22000 (29.4)	6486 (24.3)	3670 (22.2)	2307 (21.9)	4704 (18.5)	2744 (24.3)	1603 (27.0)	11022 (30.9)
	Female	49163 (72.2)	52932 (70.6)	20194 (75.7)	12844 (77.8)	8247 (78.1)	20785 (81.5)	8563 (75.7)	4338 (73.0)	24607 (69.1)
Age	18-30	19978 (29.3)	27610 (36.8)	7661 (28.7)	5101 (30.9)	3836 (36.3)	4871 (19.1)	3760 (33.3)	3333 (56.1)	7823 (22.0)
	31-50	25354 (37.2)	25326 (33.8)	9728 (36.5)	5912 (35.8)	3523 (33.4)	8194 (32.1)	3055 (27)	1426 (24.0)	9896 (27.8)
	51-70	20683 (30.4)	19995 (26.7)	8327 (31.2)	5016 (30.4)	2906 (27.5)	10806 (42.4)	3801 (33.6)	1047 (17.6)	14857 (41.7)
	71+	2109 (3.1)	2001 (2.7)	964 (3.6)	485 (2.9)	289 (2.7)	1617 (6.3)	690 (6.1)	135 (2.3)	3050 (8.6)
State	New South Wales	16602 (24.4)	21727 (29)	7581 (28.4)	4530 (27.4)	3052 (28.9)	7919 (31.1)	3533 (31.2)	1792 (30.2)	12773 (35.9)
	Victoria	22368 (32.8)	19909 (26.6)	7284 (27.3)	4083 (24.7)	2571 (24.4)	7441 (29.2)	2770 (24.5)	1733 (29.2)	7691 (21.6)
	South Australia	8031 (11.8)	6415 (8.6)	1900 (7.1)	1572 (9.5)	992 (9.4)	2068 (8.1)	1001 (8.9)	498 (8.4)	3579 (10.0)
	Queensland	7756 (11.4)	12618 (16.8)	5036 (18.9)	3103 (18.8)	1966 (18.6)	3912 (15.3)	1792 (15.8)	836 (14.1)	4842 (13.6)
	Western Australia	7007 (10.3)	8025 (10.7)	2424 (9.1)	1474 (8.9)	901 (8.5)	2041 (8.0)	895 (7.9)	387 (6.5)	3759 (10.6)
	Tasmania	2105 (3.1)	2171 (2.9)	729 (2.7)	634 (3.8)	363 (3.4)	815 (3.2)	616 (5.4)	412 (6.9)	1519 (4.3)
	Australian Capital Territory	2525 (3.7)	3388 (4.5)	1437 (5.4)	827 (5.0)	551 (5.2)	1045 (4.1)	576 (5.1)	228 (3.8)	1164 (3.3)
	Northern Territory	602 (0.9)	517 (0.7)	289 (1.1)	291 (1.8)	158 (1.5)	244 (1.0)	124 (1.1)	55 (0.9)	301 (0.8)

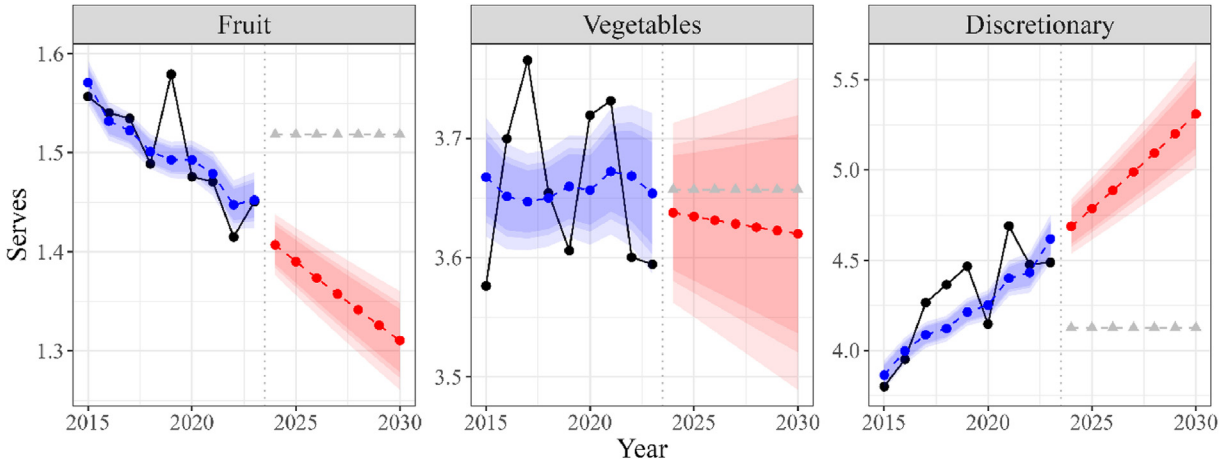
gamma GLM was fitted to each dietary intake variable, projections were made through to 2030 with a conservative 90%, 95% and 99% confidence intervals to account for the complex survey design, calculated using the ciTools package.[19] Subgroup projections were calculated by concatenating the model predictions across target subgroups; see the Supplementary Material for details. Model forecasting accuracy for the gamma GLM was determined by estimating the root median squared error[20] using an expanding window time series cross-validation method[21] as described in the Supplementary Material (Figure S1). When assessing accuracy, a lower root median squared error indicated a higher accuracy in the model. All statistical analyses were performed in R v. 4.3.1.[22]

Results

The gamma GLM accurately captured the trends in the dietary intake variables (Supplementary Table S1) and accurately forecasted fruit and discretionary intake for a time horizon of up to four years; see Supplementary Material for further details. The model coefficients for the gamma GLM can be found in the Supplementary Material (Tables S2 and S3).

Figure 1 shows the trends in fruit, vegetables and discretionary foods intake from 2015 to 2023 (blue line) compared to the no time trend model (grey line) for people who report more than zero serves; deeper looks of the no time trend models are available in

Figure 1: Trends in dietary intake over time (years, x-axis). Predicted mean dietary intake in servings for individuals who report more than zero serves (y-axis). Black is the observed sample mean over time, blue is the predicted population's servings of dietary intake, red is the forecasted intake to 2030, including a time trend and grey is the forecasted intake to 2030 with no time trend. The shaded areas show conservative 90%, 95% and 99% confidence intervals for the forecast. The dashed vertical line is to indicate where prediction ends and forecasting begins.



Figures S6–S9. A decrease in fruit self-reported intake has been observed from 1.56 servings per person per day in 2015 to 1.45 servings per person per day in 2023. If this trend continues, then the model predicts (red line) that fruit intake is likely to decrease further to 1.31 (95% CI:[1.27,1.35]) servings per day by 2030 (equivalent to a 9.66% (95% CI:[6.90%,12.41%]) decrease from 2023). Vegetable intake showed greater variation year on year ranging from 3.58 servings in 2015 to 3.77 servings in 2017 and back to 3.59 servings by 2023. Hence, the estimated average population intake was relatively stable between 2015 and 2023 (3.67 servings to 3.65 servings); the forecasted population average vegetable intake remained stable between 3.62 and 3.65 servings through to 2030. Between 2015 and 2023, observed discretionary food intake increased by 0.69 servings from 3.80 to 4.49 servings. If this trend continues, then the average intake of discretionary foods is predicted to increase by another 0.82 servings by 2030, making that a 1.51 servings (or 39.74%; 95% CI:[33.68%,45.79%]) increase in 15 years between 2015 and 2030, or 18.26% ((95% CI:[13.14%,23.39%]) increase in the 7 years between 2023 and 2030.

Consumption patterns and predicted changes in consumption were examined by sex (Figure 2) for people who report more than zero servings. A decrease in fruit intake was observed for males and females between 2015 and 2023, and if this trend continues, then fruit intake is predicted to decrease by 4.79% (95% CI:[2.05%,7.53%]) in males from 1.46 servings in 2023 to 1.39 (95% CI:[1.35,1.43]) servings per day in 2030, and 13.19% (95% CI:[10.42%,15.97%]) in females from 1.44 servings in 2023 to 1.25 (95% CI:[1.21,1.29]) servings per day by 2030. A consistent trend between males and females was also observed for discretionary food intake, albeit an increase in intake predicted instead of a decrease. Between 2015 and 2023, intake in males increased by 12.47% from 4.65 to 5.23 servings per day. If this trend continues, then a further 19.50% (95% CI:[14.34%,24.67%]) increase in consumption is predicted for males by 2030 to 6.25 (95% CI:[5.98,6.52]) servings per day. For females, intake increased by 19.05% between 2015 and 2023 from 3.15 servings to 3.75 servings, with a further increase of 21.60% (95% CI:[16.27%,26.67%]) predicted by 2030 (to 4.56 (95% CI:[4.36,4.75]) servings per day) if this trend continues.

The variation in vegetable consumption from 2015 to 2023 meant that the model struggled to capture the trend as well as other food groups. However, based on population estimates between 2015 and 2023, the model forecasted a different trajectory by sex. For females, the model predicted a slight decrease in vegetable intake of about 3.01% (or 0.11 servings; 95% CI:[0.55%,5.74%]) between 2023 and 2030, and a small increase for males, in the order of 5.10% (or 0.18 servings; 95% CI:[2.27%,7.93%]). This would leave females with a predicted mean self-reported intake of 3.55 servings per day (95% CI:[3.45,3.64]) and 3.71 servings for males (95% CI:[3.61,3.81]). The year 2021 may have been a turning point for vegetable intake in males, with a decrease in intake observed since then, but this is not captured by the 2030 prediction model.

Between 2015 and 2023, a decrease in the consumption of fruit and vegetables for people who report more than zero servings across the three older age groups was observed, but a slight increase was observed for the 18-30 year-old age group (Figure 3). Overall fruit intake in the 18-30 year-old age group decreased from 1.41 serves in 2015 to 1.31 in 2023 but a peak in intake of 1.64 serves was observed in 2019. The model predicts that fruit intake in this age group will

Figure 2: Trends in dietary intake over time (years, x-axis) for females (top) and males (bottom). Predicted mean dietary intake in servings for individuals who report more than zero servings (y-axis). Black is the observed sample mean over time, blue is the predicted population servings of dietary intake, red is the forecasted intake to 2030, including a time trend, and grey is the forecasted intake to 2030 with no time trend. The shaded areas show conservative 90%, 95% and 99% confidence intervals for the forecast. The dashed vertical line is to indicate where prediction ends and forecasting begins.

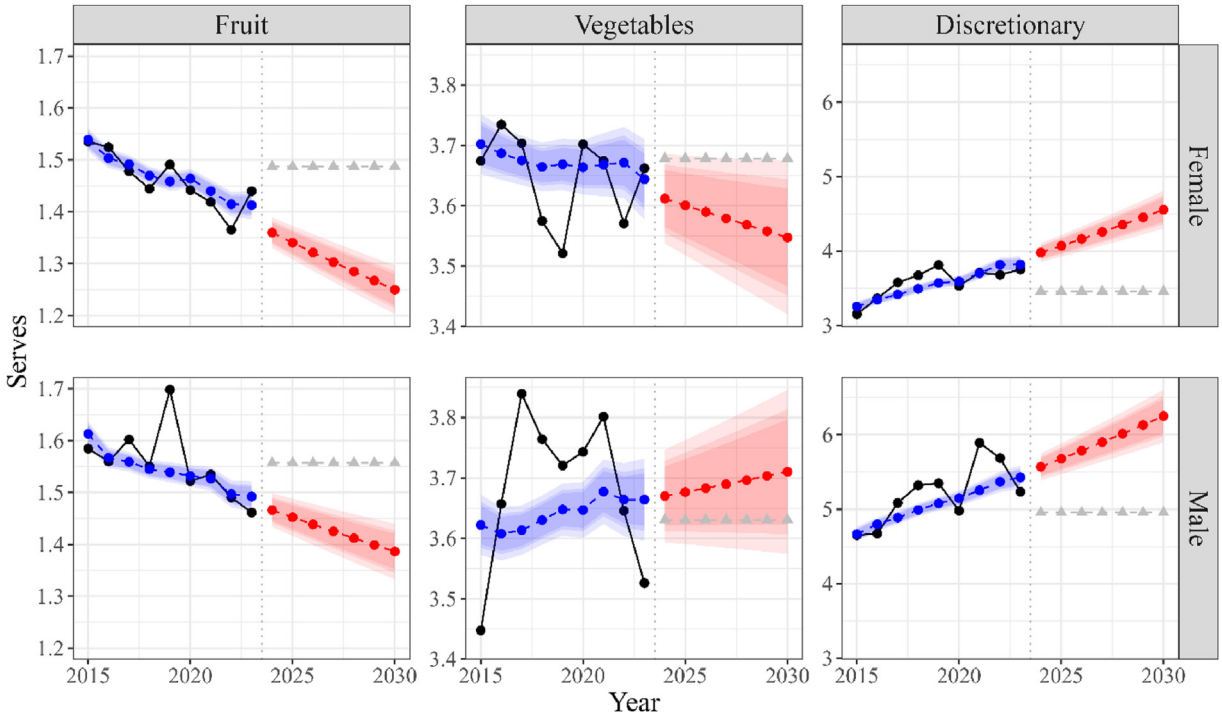
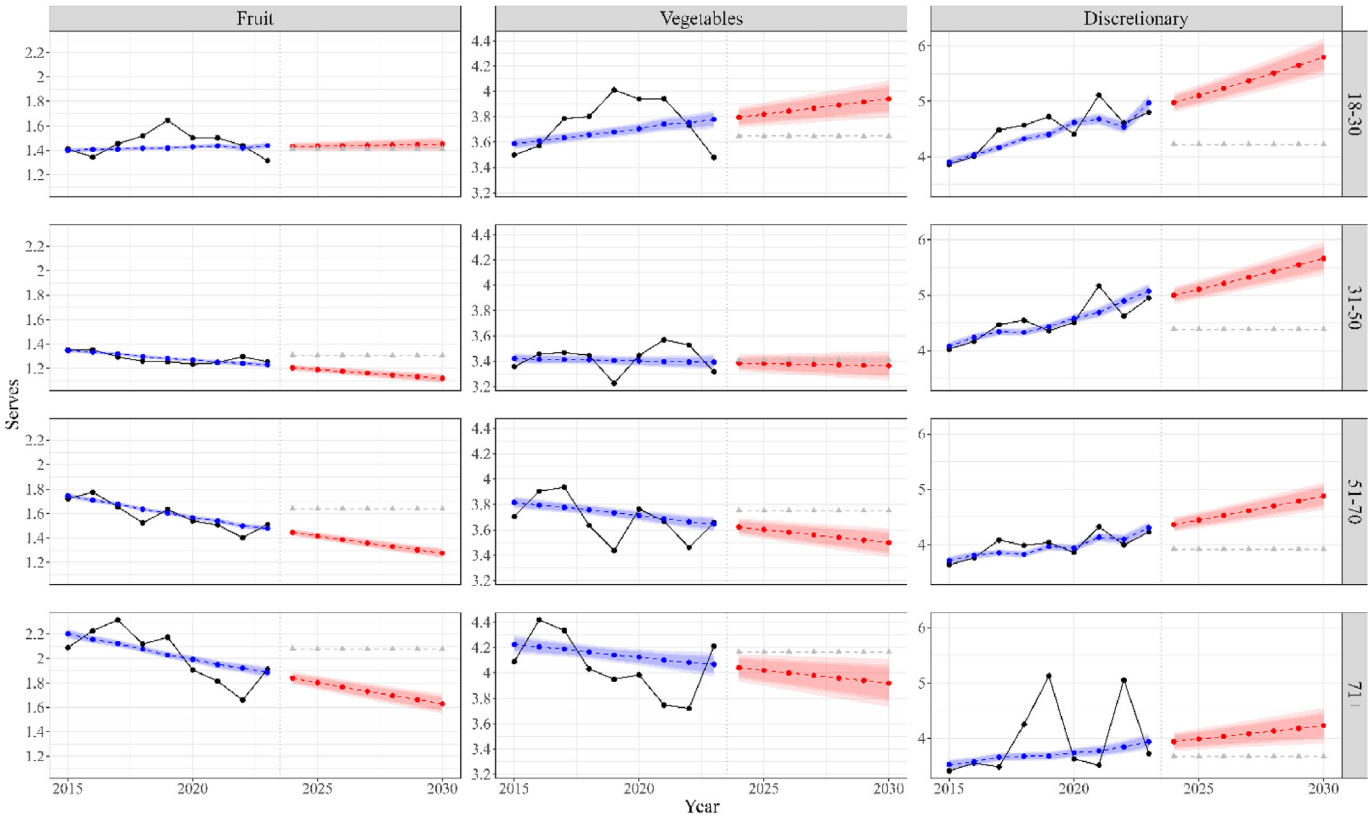


Figure 3: Trends in dietary intake over time (years, x-axis) for 18-30 (top), 31-50 (second), 51-70 (third) and 71+ (bottom row) year olds. Predicted mean dietary intake in servings for individuals who report more than zero serves (y-axis). Black is the observed sample mean over time, blue is the predicted population serves of dietary intake, red is the forecasted intake to 2030, including a time trend, and grey is the forecasted intake to 2030 with no time trend. The shaded areas show conservative 90%, 95% and 99% confidence intervals for the forecast. The dashed vertical line is to indicate where prediction ends, and forecasting begins.



increase slightly by 0.14 servings (or 10.69%; 95% CI:[7.63%,13.74%]) from 2023 through to 2030. The lowest consumption of fruit was observed for the 31-50 year-old age group, and the highest intake was observed in the 71 years and over group, however, this older age group also had the greatest decrease in fruit consumption between 2015 and 2023. The model predicts fruit intake of adults aged 71 years and over will decrease by 14.66% (95% CI:[11.52%,17.80%]) from 2023 to 2030, equivalent to a 0.46 serving or 22.01% (95% CI:[19.14%,24.88%]) decrease overall from 2015 to 2030.

There was a trend for an increase in vegetable intake for the 18-30 year-old age group between 2015 and 2021, and then there appears to be a turning point in 2021, from which point the average intake of vegetables appears to have decreased. Regardless the model predicts an overall increase in vegetable consumption for the 18-30 year-old age group from 3.48 servings in 2023 to 3.94 servings (95% CI:[3.83, 4.05]) in 2030 (equivalent to a 13.22% (95% CI:[10.06%,16.38%]) increase). Vegetable intake decreased between 2015 and 2023 for all other age groups, and the model predicts intake will continue to decrease from 2023 through to 2030 for age groups over 50 years, but to remain stable for those in the 31-50 years group. The largest decrease in vegetable intake is predicted for 71 years and over, where vegetable intake is predicted to decrease by about 0.29 serves between 2023 and 2030 (equivalent to 6.89% (95% CI:[3.56%,10.21%]) from 2023, Figure 3). There might have been a larger decrease in intake predicted for this age group, but an increase observed for 2023 pulled the prediction model up to a less pessimistic outcome. Whether this increase indicates a true upward turn in vegetable intake needs to be monitored.

Discretionary food intake for people who report more than zero servings has increased across all age groups between 2015 and 2023, and the model predicts the largest increase in discretionary food intake to be in the 18-30 and 31-50 year-old age groups. Intake in these groups is predicted to increase from 4.80 in 2023 to 5.80 serves (95% CI:[5.54,6.06]) in 2030 for 18-30 year-olds (equivalent to a 20.83% increase; 95% CI:[15.42%,26.25%]) and 4.95 to 5.67 servings (95% CI:[5.44, 5.89]) in 31-50 year-olds (equivalent to a 14.55% increase; 95% CI:[9.90%,18.99%]). We note that the 71 years and over age group had highly variable intakes of discretionary food over time, in particular in 2019 and 2022, which flattened their predicted intake to have the lowest predicted increase to 2030 (13.71% increase (95% CI:[7.26%,20.16%]) from 2023, Figure 3).

Discussion

Rebalancing population diets towards higher consumption of fruit and vegetables and lower consumption of discretionary foods is a key public health focus globally to promote health and well-being, and reduce the risk of weight gain and chronic disease.[9,16,23] Australia's National Preventive Health Strategy sets out ambitious targets for the population to achieve an average intake of 2 servings of fruit and 5

servings of vegetables by 2030, and for the energy intake from discretionary foods to reduce to less than 20% of total energy.[9] The results of this modelling suggest that without significant effort and intervention, fruit intake will decline by almost 10% in the population overall by 2030, with a decline in all age and sex groups predicted with the exception of 18-30 year olds. The model also predicted that vegetable intake will remain approximately stable between 2023 and 2030 for the population overall, however intake was predicted to decrease in females and most age groups but an increase in males and those in the 18-30 year-old age group. Young adults (18-30 years) were the only subgroup analysed here showing improvement in fruit and vegetable intake, with the model predicting an increase in consumption to 2030 of about 11% and 13%, respectively. However, these increases in fruit and vegetable intake were offset by predicted increases in discretionary foods and beverages as well. Between 2023 and 2030, discretionary food intake of young adults was predicted to increase by almost 21%. In fact, discretionary food intake in all subgroups of the population was predicted to increase, with an 18% increase predicted for the population overall. This is problematic given Australians' current intakes of discretionary foods are already twice the recommended amounts in our Dietary Guidelines,[6] and we are aiming for a decrease from current intakes, where discretionary foods contribute about 35% of total energy intake,[24] to <20% by 2030.[9] To the authors knowledge, this is the first study in Australia to predict changes in eating habits in a way that allows direct comparison of population diets to national priorities and government targets. For Australia, these data suggest achieving these targets by 2030 will require significant effort to not only halt the current trends in consumption but, in fact, reverse these trends to achieve increased fruit and vegetable and decreased discretionary food and beverage consumption within the next 7 years.

Decreasing fruit and vegetables consumption in most subgroups of the population, suggests achieving the population dietary targets of 2 servings of fruit and 5 servings of vegetables per day by 2030 will be a challenge. Many countries have similar targets for fruit and vegetables, which are promoted through information and awareness-type social marketing campaigns such as Go for 2&5 in Australia and the 5-A-Day type campaigns in countries such as Canada, Denmark, the USA and the UK, and similar initiatives in Spain, France and Germany. Further to this, there have been many research trials, community programs, and government initiatives that have tried to increase fruit and vegetable consumption.[25,26] Some have demonstrated small increases in consumption but rarely have large, lasting changes in consumption been achieved at scale.[25,27,28] Comparatively, there have been fewer initiatives focused on reducing intake of discretionary food and beverages. Strategies that address portion size and improve meal quality (by replacing discretionary foods with healthier items) have been shown to be effective in reducing the dietary energy from discretionary foods,[29–31] and personalised messages are more effective than standard nutrition advice in reducing intake.[32] Other countries have introduced regulation mechanisms, like sugar-sweetened beverage taxes,[33] to change behaviour around discretionary food and beverage intake. Australia does not have a sugar tax at present, and interventions targeting discretionary foods have not been tested and scaled up like they have for fruit and vegetables, or been shown to have lasting success in changing eating habits within Australia, and the most effective way to do this remains unclear. These data could help to inform tailored messages or interventions for specific food groups and population subgroups most in need of support for behaviour change.

Due to changes in the methods used in National Nutrition Surveys, it is difficult to directly compare dietary intake data from the 1995 Australian National Nutrition Survey to the most recent 2011-12 survey. However, since 2018, the Australian Bureau of Statistics has consistently published apparent consumption data using purchase data from the food retail sector.[34] These data suggest that the five-year change to 2022-23, shows a 2.4% decrease in the purchase of vegetable products, an 11.0% decrease in the purchase of legumes and pulses, 7.9% decrease in fruit and a 10.1% increase in the purchase of snack foods.[35] The trend in these data largely supports the past trends observed in the self-reported survey data used as the foundation of the prediction modelling presented here, and the growing evidence of a gradual decline in diet quality is concerning. Nonetheless, monitoring of preventive health behaviours is important[9] as it has the potential to drive improvements in prevention by highlighting where additional effort is needed and guiding the design and delivery of interventions.

This analysis used data from the CSIRO Healthy Diet Score survey, which relies on individuals to report their intake on short questions. The survey asks about fruit intake in a single item, but vegetable intake using 3 items and discretionary foods and beverages using 11 items allowing for good coverage of the food group categories as described in the Australian Dietary Guidelines.[16] Like most dietary assessment methods, short questions are prone to bias, and responses are likely to overestimate intakes of healthy foods like fruit and vegetables, and underestimate intake of discretionary foods and beverages. However, data has been collected using this survey and the same methodology since 2015. A consistent methodology, with the large sample size and data weighted to better reflect the demographic composition of the broader Australian population are strengths of the study and allowed for the prediction modelling to be conducted for the population overall and by subgroups of age, sex and state of residence. Consistent with dietary guidance in Australia, the presentation of results by age and sex was the focus; however, other covariates reflecting socioeconomic status could also be of interest for future research. Despite being a unique data asset, there were some outlier years that would have influenced the projections. Fruit intake in 2019 was higher than years around it, and vegetable intake over the years between 2015 and 2023 was highly variable. Although our model was robust to the fruit intake observed in 2019, the effect of outliers should continue to be monitored in the coming years.

The gamma hurdle regression model provides an interpretable and approachable modelling technique to understand the overarching trends in dietary intake in the Australian population. In particular, the gamma model is designed to capture the change in mean value for right-skewed data, which all dietary intake variables were, and has found success in other areas of nutritional modelling.[36] However, because the gamma component of the model only captures individuals who report more than zero servings on a dietary variable, there is a possibility we are overestimating the expected number of serves across all target subgroups. Despite this, the trends observed in the dietary intake variables remain consistent. Further, our model does not aim to explain the change in dietary intake observed here,

simply to capture the population trends in intake. There are different possible mechanisms that could influence this change in dietary intake, such as the increase in costs for fresh fruits and vegetables and discretionary foods.[37] Understanding how different mechanisms influence dietary intake at a population level would allow greater identification and evaluation of possible interventions and is an area of future research. Also, there are only nine years' worth of survey data available, with time trends observed in the data becoming more apparent after the first few years of data. To validate the observed trends in dietary intake, further monitoring through increased survey efforts is needed.

Conclusion

This analysis used nine years of self-reported food intake data to predict trends in intake of fruit, vegetables, and discretionary foods out to 2030. Consumption of fruit and vegetables is a key marker of a healthy diet and is associated with improved health outcomes. Conversely, discretionary foods are associated with weight gain and disease. Australia has set population targets for the consumption of these food groups, and the modelling presented in this paper suggests that, without significant intervention, discretionary food intake will continue to increase, and fruit and vegetable intake will continue to decrease in almost all population age groups, with 18-30-year-olds a possible exception. Continuously monitoring dietary intake will be important to assess progress against National Preventive Health Targets and to inform targeted intervention to improve diet quality and health outcomes.

Author contributions

GAH was responsible for conceptualising this paper. DLK and GAH were responsible for data curation. MR developed the method and conducted the statistical modelling and analysis. GAH and MR wrote the original draft of the manuscript. GAH, DLK and MR reviewed and edited the draft. GAH, DLK and MR were responsible for the decision to submit the manuscript. The authors had unrestricted access to the study data and retained the ultimate responsibility for the decision to submit the paper for publication.

Ethical approval

This study was approved by the CSIRO Health and Medical Human Research Ethics Committee Low Risk Review Panel (LR 29/2016).

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data sharing

The terms and conditions associated with the data collection survey and the ethics approval does not allow participant data to be shared with a third party. The estimates and results of the analysis are available in the figures presented and in tables as an appendix. The mathematical formulas are also available as an appendix.

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References

1. Boeing H, Bechthold A, Bub A, Ellinger S, Haller D, Kroke A, et al. Critical review: vegetables and fruit in the prevention of chronic diseases. *Eur J Nutr* 2012;**51**(6):637–63.
2. Institute for Health Metrics and Evaluation. *Findings from the global burden of disease study 2017*. Seattle, WA: IHME; 2018.
3. Australian Institute of Health and Welfare. *Australian burden of disease study 2023*. Canberra: AIHW; 2023.
4. Food and Agriculture Organisation of the United Nations. *Food-based dietary guidelines*. FAO; 2024. Available from: https://www.fao.org/nutrition/education/food-based-dietary-guidelines.
5. Australian Bureau of Statistics. Australian health survey: consumption of food groups from Australian dietary guidelines. In: *ABS*. ABS; 2016.
6. Hendrie GA, Baird D, Golley RK, Noakes M. The CSIRO healthy diet score: an online survey to estimate compliance with the Australian dietary guidelines. *Nutrients* 2017;**9**(1):47.
7. Schwingshackl L, Schwedhelm C, Hoffmann G, Lampousi A, Knüppel S, Iqbal K, et al. Food groups and risk of all-cause mortality: a systematic review and meta-analysis of prospective studies. *Am J Clin Nutr* 2017;**105**(6):1462–73.
8. Lal A, Peeters A, Brown V, Nguyen P, Tran HNQ, Nguyen T, et al. The modelled population obesity-related health benefits of reducing consumption of discretionary foods in Australia. *Nutrients* 2020;**12**(3).
9. Department of Health. *National preventive health Strategy 2021–2030* [cited 2024 02 May]. Available from: https://www.health.gov.au/resources/publications/national-preventive-health-strategy-2021-2030; 2021.
10. Martin-Moreno JM. Facing the COVID-19 challenge: when the world depends on effective public health interventions. *South Eastern European Journal of Public Health* 2023. https://api.semanticscholar.org/CorpusID:218917271.
11. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, et al. Strengthening the reporting of observational studies in epidemiology-nutritional Epidemiology (STROBE-nut): an extension of the STROBE statement. *PLoS Med* 2016;**13**(6):e1002036.
12. Hendrie GA, Rebuli MA, Golley RK. Reliability and relative validity of a diet index score for adults derived from a self-reported short food survey. *Nutr Diet* 2017;**74**(3):291–7.
13. Golley RK, Hendrie GA, McNaughton SA. Scores on the dietary guideline index for children and adolescents are associated with nutrient intake and socio-economic position but not adiposity. *J Nutr* 2011;**141**(7):1340–7.
14. Hendrie G, Baird D, Golley R. CSIRO healthy diet score: a short online survey to measure compliance with food-based dietary guidelines. *Ann Nutr Metabol* 2019;**75**:199.
15. Hendrie GA, Rebuli MA, Golley RK, Noakes M. Adjustment factors can improve estimates of food group intake assessed using a short dietary assessment instrument. *J Acad Nutr Diet* 2018;**118**(10):1864–73.
16. National Health and Medical Research Council. *Australian dietary guidelines canberra: NHMRC*. Available from: https://www.health.gov.au/resources/publications/the-australian-dietary-guidelines; 2013.
17. Australian Bureau of Statistics. *Population: census [internet]*. ABS; 2021. Available from: https://www.abs.gov.au/statistics/people/population/population-census/latest-release.
18. Cragg JG. Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica* 1971;**39**(5):829–44.
19. Harman J, Avery M. ciTools: confidence or prediction intervals, quantiles, and probabilities for statistical models. 0.6.1 ed2020.
20. Armstrong JS, Grohman MC. A comparative study of methods for long-range market forecasting. *Manag Sci* 1972;**19**(2):211–21.
21. Hewamalage H, Ackermann K, Bergmeir C. Forecast evaluation for data scientists: common pitfalls and best practices. *Data Min Knowl Discov* 2023;**37**(2):788–832.

22. R Core Team. *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistial Computing; 2023.
23. U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary guidelines for Americans, 2020-2025 and online materials*. Available from: https://www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials; December 2020.
24. Australian Bureau of Statistics. *Australian health survey: nutrition first results - foods and nutrients*. ABS; 2011. Available from: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/australian-health-survey-nutrition-first-results-foods-and-nutrients/latest-release.
25. Rekhy R, McConchie R. Promoting consumption of fruit and vegetables for better health. *Have campaigns delivered on the goals? Appetite* 2014;**79**:113–23.
26. Wolfenden L, Barnes C, Lane C, McCrabb S, Brown HM, Gerritsen S, et al. Consolidating evidence on the effectiveness of interventions promoting fruit and vegetable consumption: an umbrella review. *Int J Behav Nutr Phys Activ* 2021;**18**(1):11.
27. Civic Creative Health Claims in Food Advertising. *Horticulture innovation Australia*. 2015.
28. Woolcott Research & Australia. Department of health and ageing. *Evaluation of the national Go for 2&5 campaign* 2007. Available from, https://catalogue.nla.gov.au/catalog/3916640.
29. James-Martin G, Baird DL, Hendrie GA. Strategies to reduce consumption of unhealthy foods and beverages: scenario modeling to estimate the impact on the Australian population's energy and nutrient intakes. *J Acad Nutr Diet* 2021;**121**(8):1463–83.
30. Grieger JA, Johnson BJ, Wycherley TP, Golley RK. Comparing the nutritional impact of dietary strategies to reduce discretionary choice intake in the Australian adult population: a simulation modelling study. *Nutrients* 2017;**9**(5).
31. Grieger JA, Wycherley TP, Johnson BJ, Golley RK. Discrete strategies to reduce intake of discretionary food choices: a scoping review. *Int J Behav Nutr Phys Activ* 2016;**13**:57.
32. Livingstone KM, Celis-Morales C, Navas-Carretero S, San-Cristobal R, Forster H, Woolhead C, et al. Personalised nutrition advice reduces intake of discretionary foods and beverages: findings from the Food4Me randomised controlled trial. *Int J Behav Nutr Phys Activ* 2021;**18**(1):70.
33. World Health Organization. *Global report on the use of sugar-sweetened beverage taxes, 2023*. Report No.: Licence: CC BY-NC-SA 3.0 IGO; 2023.
34. *Australian Bureau of statistics apparent consumption of selected foodstuffs, Australia methodology*. ABS; 2022-23. Available from: https://www.abs.gov.au/methodologies/apparent-consumption-selected-foodstuffs-australia-methodology/2022-23.
35. Australian Bureau of Statistics. *Apparent consumption of selected foodstuffs*. Australia: ABS; 2022-23. Available from: https://www.abs.gov.au/statistics/health/health-conditions-and-risks/apparent-consumption-selected-foodstuffs-australia/latest-release.
36. Ruf A, Neubauer AB, Ebner-Priemer U, Reif A, Matura S. Studying dietary intake in daily life through multilevel two-part modelling: a novel analytical approach and its practical application. *Int J Behav Nutr Phys Activ* 2021;**18**(1):130.
37. Australian Bureau of Statistics. *Australian dietary guidelines price indexes*. ABS; 31 January 2024. Available from: https://www.abs.gov.au/articles/australian-dietary-guidelines-price-indexes.

Appendix A Supplementary data

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