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Sustainability and cost of typical and heart-healthy dietary patterns in Australia

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ABSTRACT

Study objective: The aim was to quantify and compare the environmental and financial impact of two diets: a heart-healthy Australian diet (HAD) and the typical Australian diet (TAD).
Design: The study involved a secondary analysis of two modelled dietary patterns used in a cross-over feeding trial.
Setting: The evaluation focused on two-week (7-day cyclic) meal plans designed to meet the nutritional requirements for a reference 71-year-old male (9000 kJ) for each dietary pattern.
Main outcome measures: The environmental footprint of each dietary pattern was calculated using the Global Warming Potential (GWP*) metric, taking into account single foods, multi-ingredient foods, and mixed dishes. Prices were obtained from a large Australian supermarket.
Results: The HAD produced 23.8 % less CO_2 equivalents (CO_2e) per day (2.16 kg CO_2e) compared to the TAD (2.83 kg CO_2e per day). Meat and discretionary foods were the primary contributors to the environmental footprint of the TAD, whereas dairy and vegetables constituted the largest contributors to the HAD footprint. However, the HAD was 51 % more expensive than the TAD.
Conclusion: Transitioning from a TAD to a HAD could significantly reduce CO_2 emissions and with benefits for human health and the environment. Affordability will be a major barrier. Strategies to reduce costs of convenient healthy food are needed. Future studies should expand the GWP* database and consider additional environmental dimensions to comprehensively assess the impact of dietary patterns. Current findings have implications for menu planning within feeding trials and for individuals seeking to reduce their carbon footprint while adhering to heart-healthy eating guidelines.

1. Introduction

Climate change stands as one of the biggest global issues of our time [1]. Without decisive action, projections from the Intergovernmental Panel on Climate Change (IPCC) report that temperatures exceeding 1.5 °C and 2 °C above pre-industrial levels will become a reality in the 21st century [2]. Simultaneously, the current food systems are contributing >30 % of total greenhouse gas (GHG) emissions, up to 80 % of biodiversity loss and 70 % of freshwater losses [3,4]. A major challenge is for food production to meet the nutritional needs of a predicted 10 billion people by 2050 [5]. A shift towards more sustainable healthy diets will be needed to feed the population while decreasing GHG emissions and broadening climate change adaptation options [3]. Defined by the Food and Agriculture Organisation (FAO), sustainable healthy diets promote individual health and wellbeing, exhibit low environmental impact, are accessible, affordable, safe and equitable, and culturally acceptable [6].

Australia grapples with the tangible impacts of climate change, having already experienced an average warming of 1.47 °C since 1910 [7]. This warming trend has manifested in increasingly severe heatwaves, droughts, acidified oceans and rising sea levels [7]. Notably,

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Australia's agricultural sector accounts for 80.7 million metric tons of CO_2e, ranking food production fourth highest contributor after electricity, energy and transport [8]. However, this metric fails to account for additional food processing, transport, retail, consumption, and waste emissions.

The Global Warming Potential over 100 years (GWP_{100}) has been widely employed metric in previous studies to measure the footprint of dietary patterns [9,10]. This metric evaluates the cumulative contribution of CO_2e radiation over a century-long timeframe [11]. However, its application becomes problematic when short-lived climate pollutants are factored in, as it fails to adjust for their varying atmospheric lifetimes and impacts on the climate system over time [12]. Highlighting this limitation, the IPCC [13], and Paris Agreement [14], have indicated that the GWP_{100} metric lacks particular significance, meaning that it cannot effectively gauge alignment with climate stabilisation goals. In contrast, the GWP* metric represents a relatively novel approach. It assesses global warming potential from short-lived GHG in comparison to CO_2. Short-lived GHG from farming and livestock production, such as methane, are responsible for 35 % of food-system GHG emissions and are much more potent than CO_2 [15]. While methane is the dominant contributor, it breaks down in about 12 years, unlike CO_2, which can persist for centuries [16]. Consequently, relying solely on the GWP_{100} can lead to a substantial overestimation—up to three to four times—of the observed global warming effect [17].

Numerous factors influence food choices and dietary habits, including convenience, affordability, taste preferences, nutritional value, accessibility, culinary proficiency, and sociocultural norms [18–22]. The growing demand for convenience has transformed the food landscape, with availability of ready-to-eat meals and prepackaged products still increasing. The market for ready meals (including ambient, chilled, and frozen products) is growing rapidly, with the number of products increasing by an average of 13 % each year [23]. However, if not thoughtfully selected or integrated into a well-balanced menu plan, an increased reliance on convenience foods compromises overall dietary quality. Higher consumption of products rich in added fat, sugar, salt, and additives needed for preservation and extended shelf life may contribute to or exacerbate health issues such as obesity and non-communicable diseases. On the other hand, not all ready-to-eat meals or prepackaged products are unhealthy. Techniques such as freezing for preservation allow consumers to purchase healthy foods and meals [24], including frozen vegetables and fruits, year-round according to their preferences. Additionally, for individuals with limited culinary skills or time constraints, these convenient food choices can play a vital role in meeting dietary needs and maintaining overall well-being.

Therefore, the current study evaluates two meal plans: a heart-healthy Australian diet (HAD) that aligns with the Australian Dietary Guidelines [25] and heart-healthy dietary targets [26] and a typical Australian diet (TAD), which reflects population-level intakes (less healthy) consistent with the 2020–21 Australian Apparent Consumption report [27]. These had been used in randomised, cross-over feeding trial [27]. Both meal plans were intentionally designed for convenience, requiring minimal cooking skills. They each included ready-to-eat meals available from a large Australian supermarket chain and meals needing minimal preparation (sandwiches or wraps) to ensure adherence and consistent intake across participants. This study demonstrates the feasibility of achieving national dietary guidelines for individuals with limited time or food preparation skills, while aiming to explore the financial and environmental impacts of these meal plans. Specifically, the objectives of this study were to (1) quantify the carbon footprint (GWP*) of the two dietary patterns (HAD and TAD) and (2) assess the affordability (financial cost) of both diets. This study provides insight into balancing health, cost, and environmental considerations in dietary choices, which have not been thoroughly examined before.

2. Methods

2.1. Source of dietary data

The paper utilises two dietary patterns, which were employed in a randomised, cross-over feeding trial involving 34 healthy Australian adults [27]. In the feeding trial, a 7-day menu cycle for each diet was repeated over two weeks, where all meals, snacks and selected beverages were provided to volunteers [27]. The TAD was designed to reflect the common food and nutrient intake patterns in Australian adults at the time of study inception, derived from the Australian's Apparent Consumption report [27]. This report comprises the quantity of purchased food and non-alcoholic beverages from food and retail sectors from July 2020 to June 2021 [28]. HAD meal plans align with the Australian Dietary Guidelines [29], Acceptable Macronutrient Distribution Ranges (AMDR) and key nutrient intake recommendations for adults [25]. Additionally, these recommendations conform to the heart-healthy eating guidelines [26]. The meal plans selected were designed to meet the nutritional requirements of a 71-year-old male, aiming to meet estimated energy requirements [EER] of 9000 kJ/day [27]. These specific targets were based on the mean EER among participants who completed the feeding study, and aligned with reference age and sex outlined in similar modelled studies [9,30].

Nutritional data was first generated using FoodWorks (Professional version 10; Xyris Pty Ltd., Brisbane, Australia). Subsequently, the list of individual food and beverage items was exported from FoodWorks and managed in Microsoft Excel [Version 16.0, Redmond, WA: Microsoft Corporation] to assign GWP* values and calculate financial costs.

2.2. Climate impact assessment

The methodology for identifying and calculating GWP* values of foods and beverages that made up the two dietary patterns relied on a published database of Australian food and beverages [32], which contains GWP* values for 232 Australian food and beverage products. This database utilises a Life Cycle Analysis (LCA) approach, considering land and water use as well as gases produced throughout the food production lifecycle [33]. However, emissions from food packaging, kitchen storage, and preparation were not factored into the database due to a lack of valid data.

To apply the database [32], a systematic approach outlined below and illustrated in **Fig. S1** was followed. This method, informed by published research [34,35], allowed for calculation of each ingredient's GWP* for all products provided in the meal plans. This included multi-ingredient foods, beverages and mixed dishes, which were then aggregated to the food group level. While not without limitations, this approach offers improved accuracy of estimations, which is important given the constraints of the limited number of foods in the GWP* database. Further, it enabled inclusion of all diverse food products provided and allowed for a more comprehensive and representative comparison of both diets.

First, food or beverage products that could be directly classified and calculated using existing items in the database were assigned corresponding GWP* values. For example, full cream cow's milk could be coded as 'Whole Milk', with a corresponding value of 1.23 kg CO_2/kg. However, due to the database's limited size ($n = 232$), certain assumptions had to be made for missing food items or ingredients, i.e. quinoa was not available in the database; therefore, brown rice, the best alternative, was used.

To assess multi-ingredient products or mixed dishes, we initially estimated the proportions of ingredients using the nutrition information panels on food packaging. This data was gathered from specific commercial products acquired from local grocery stores or manufacturer websites. This information was essential for determining the GWP* values for each ingredient. For example, in the case of the product 'frozen mixed berries', the composition consisted of 37 % blueberries, 33 % strawberries, and 30 % raspberries. Utilising these proportions, we calculated the total GWP* value by multiplying the portion of each ingredient corresponding to the database [32] and then summing them to obtain the total GWP value for that product.

When none of the above methods were feasible, we determined the GWP* value by either referencing comparable products already available within the database [32], utilising standard recipes sourced from the AUSNUT 2011–2013 food recipe file [36], or consulting Australian websites. These sources were selected based on the professional judgment of research dietitians.

2.3. Financial cost analysis

The financial cost of each diet was determined using prices from the Coles online supermarket, with data updated as of April 4th, 2024. This ensured consistency in pricing across both dietary patterns and accounted for any product price variations over time.

The total price of both diets was calculated over a two-week period. Special price promotions on the day were used and were considered to accurately reflect the true costs incurred. Even for bulk items that might not be fully consumed within the two-week period, such as a single tub of margarine or a jar of sauce, the total price for that product was accounted for and captured in the total cost for each diet. This approach ensured that the smallest necessary quantities required to be purchased to meet the meal plan serving sizes were represented in the total price, regardless of any leftover portions after the two weeks.

2.4. Data synthesis

To calculate the GWP* values, individual food and beverage items from the seven-day meal plans for both dietary patterns were combined, resulting in total GWP values per week. These weekly values were then divided by seven to derive the average GWP* values per day. To project these values over a year, we multiplied the average GWP* value and daily costs by 365.

Given our consideration of the true costs of foods over two weeks, which included bulk items needing only one purchase (like a jar of peanut butter), we divided the two-week costs by two to determine weekly expenses. Additionally, costs per gram of each food or beverage item were calculated to conduct a more detailed breakdown of expenditure per 1000 kJ.

For each dietary pattern, data was categorised according to eight food groups: fruit, vegetables, grains, dairy, meat, meat alternatives, discretionary foods, and oils. To ensure the total cost of mixed dishes or multi-ingredient products was accurately captured, an additional category labelled ‘water’ was added to cover the proportion of water they contained. These food groupings align with those outlined in the Australian Guide to Healthy Eating [37], which includes discretionary foods and oils. Additionally, a distinct category for legumes, nuts, and seeds, labelled ‘meat alternatives,’ to better represent the trend towards vegetarian and vegan diets, which often rely on these plant-based protein sources known for their smaller carbon footprint was created.

3. Results

The nutritional profiles of the two dietary patterns are summarised in Table 1. The HAD, which focuses on incorporating whole grains, vegetables, fruits, and legumes, provides almost 300 % more dietary fibre than the TAD, exceeding the recommended intake of at least 25 g per day [38]. The HAD aligns more closely with established nutrient targets [39] that support lower risk for cardiovascular disease [40–44]. This includes staying below the recommended targets for trans-fat, saturated fat, added sugars, and sodium/potassium ratio, while exceeding the recommendations for beneficial nutrients such as eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and α-linolenic acid (ALA) [38,45,46]. However, the HAD did exceed the recommended sodium intake targets [38], which is not surprising given the reliance on convenience and ready-made meals in our meal plans relevant to the feeding trial. However, the sodium content still remained nearly 25 % lower than that of the TAD. A dietary pattern similar to the HAD can be modified to reduce sodium content to recommended levels through targeted strategies. These include carefully scrutinising healthy products and selecting those with the lowest sodium content, advocating for manufacturers to reduce sodium in their offerings further, minimising the consumption of ready-made meals, and increasing the intake of fresh vegetables, legumes, fruits, and whole grain products. In contrast, the TAD contained higher levels of saturated fat, trans-fat, higher sodium/potassium ratio and more added sugars compared to HAD while falling short of ALA, EPA and DHA. Specifically, the HAD contained 87 % more ALA, and 2.4 % more EPA/DHA than the TAD.

The TAD had a higher climate footprint with a total GWP* of 2.83 kg CO_2e produced per day, compared to the HAD, which had a 23.8 %

Table 1
Nutritional differences between the Heart-healthy Australian diet (HAD) and the Typical Australian Diet (TAD).

	HAD[a]	TAD[b]
Macronutrient distribution (%) per day		
Protein	20.0	13.4
Carbohydrate	43.6	40.6
Fat	30.6	44.3
Saturated fat [RI: <10 % EI][c]	8.4	21.8
Trans fat [RI: <1 % EI][c]	0.2	0.8
Specific nutrients per day		
Added sugars (g) [RI: <25 g/day][d]	14.7	35.6
EPA & DHA (mg) [RI: 250–500 mg][c]	616	601
ALA (g) [RI: 1 g][c]	3.3	1.8
Linoleic acid (g) [RI: 4–10 % EI][c]	17.5	9.3
Sodium (mg) [RI: <2000 mg][c]	2461	3254
Dietary fibre (g) [RI: ≥25 g/day][e]	55.1	13.8
Potassium (mg)	4492	2064
Sodium/potassium [RI:<0.6 mg/mg][f]	0.55	1.58
Magnesium (mg)	488	206
Calcium (mg)	1159	820
Phosphorus (mg)	1807	1187
Iron (mg)	14.0	9.4
Zinc (mg)	12.8	9.7
Selenium (μg)	74	68
Iodine (μg)	167	143

RI (Recommended intake).
[a] Average recommended serves per day with the Australian Dietary Guidelines [29].
[b] Apparent daily consumption per capita for all Australians 2020–202 [28].
[c] Recommended nutrient targets as per Heart Foundation [39].
[d] Recommended daily limit per American Heart Association. Recommendation of 25 g/day for females and 36 g/day for males [73].
[e] Recommended dietary fibre intake as per NHMRC. Recommendation of 25 g/day for females and 30 g/day for males [38].
[f] Recommended sodium/potassium ratio as per WHO targets for sodium and potassium [74].

Table 2
Carbon dioxide equivalents (kg CO_2e) produced by the Heart-healthy Australian diet (HAD) and the typical Australian diet (TAD) per day, week and year, assessed using the GWP* (global warming potential star).

	Typical Australian Diet	Heart-healthy Australian diet
Kg CO_2e		
Per day	2.83	2.16
Per week	19.79	15.09
Per year	1032.07	786.96
Cost ($AUD)		
Per day	14.76	22.33
Per week	103.30	156.29
Per year	5386.52	8149.17
Per/1000 kJ	1.64	2.48

lower CO_2 emission of 2.16 kg CO_2e per day (Table 2). In terms of cost, the HAD was 51.3 % more expensive than the TAD diet (Table 2), representing an additional $52.98 per week. Over the course of a year, this would translate to a difference in food costs of $2762.65.

The food groups contributing the most to the climate footprint and financial cost varied across the two dietary patterns (Fig. 1). Discretionary foods, which are energy, dense, nutrient-poor foods, emerged as one of the highest contributors to CO_2e in the TAD (Fig. 1A), while in the HAD, it was one of the lowest contributors given the very low amounts included. Similarly, vegetables and meat alternatives had a low impact within TAD (0.53 and 0.20 kg CO_2e, respectively), whereas these were substantially higher (2.93 and 1.26 kg CO_2e, respectively) in the HAD. Dairy, vegetables, and meat collectively accounted for over two-thirds of the CO_2e in the HAD, whereas meat and discretionary foods contributed over 50 % of the total CO_2e footprint for the TAD. Additionally, oils and grains consistently exhibited low emissions for both diets. Financial costs also differed across the two dietary patterns based on food groups (Fig. 1B). For HAD, the main contributors to the total weekly expense were vegetables and fruit, accounting for 48.6 % of the overall cost. Conversely, in the TAD, discretionary foods made up 28.8 % of cost, while grains constituted 19.2 % of total expenditure.

The top five food items contributing to climate footprint in the two distinct dietary patterns are presented in Table 3. Across both diets, the primary contributors, were animal-based products, predominantly from the meat and dairy food groups. Processed beef, cheese, meat pie, processed pig meat, and whole milk emerged as the top contributors for the TAD. Conversely, cheese, yogurt, processed beef, processed chicken meat, and orange juice were the key contributors to the climate footprint for the HAD.

Table 3
Top five food items having the highest produced GWP* (kg CO_2e) per week for the Heart-healthy Australian diet (HAD) and the typical Australian diet (TAD).

Top contributors	HAD (kg CO_2e per week)		TAD (kg CO_2e per week)	
First	Cheese	2.05	Processed beef	5.40
Second	Yogurt	1.71	Cheese	2.31
Third	Processed beef	1.66	Meat pie	1.95
Fourth	Processed chicken meat	0.91	Processed pig meat	1.27
Fifth	Orange juice	0.78	Whole milk	1.06

4. Discussion

To our knowledge, this is the first study to investigate both the

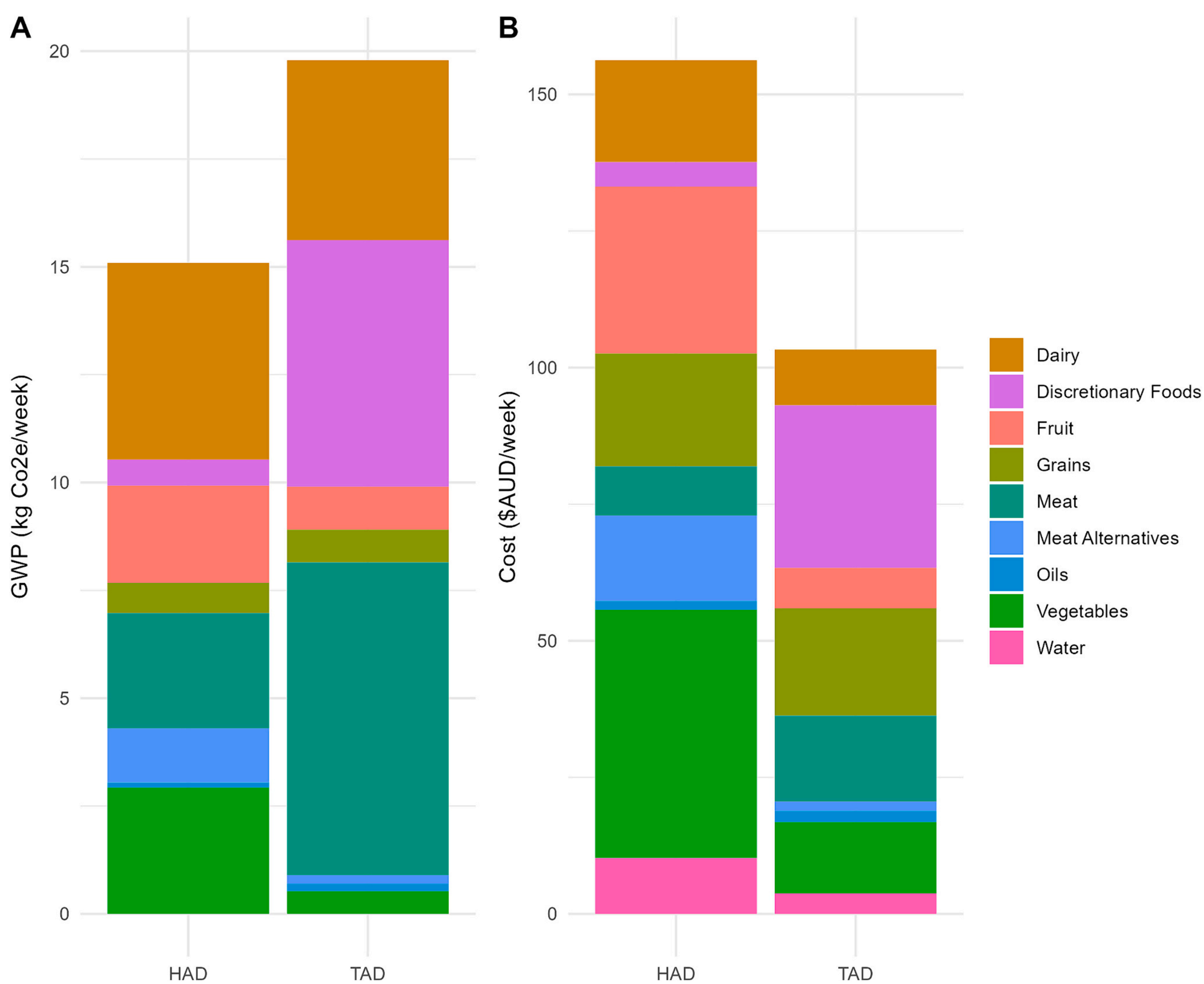

Fig. 1. (A) Cumulative climate footprint contribution (in kg CO_2e) over a 7-day (week) period for each food group in both the Heart-healthy Australian diet (HAD) and the Typical Australian Diet (TAD). **(B)** Cumulative costs (in Australian dollars) over a 7-day (week) period for each food group in both the HAD and the TAD. Water was included as a distinct food group category to accurately reflect the water content and ensure precise estimation of total costs in multi-ingredient products and mixed dishes.

nutritional quality and sustainability along with affordability of two modelled dietary patterns, namely a heart-healthy diet and a typical Australian diet. While neither diet achieved climate neutrality ($CO_2e < 0$), the heart-healthy dietary pattern demonstrated a notable environmental advantage, with 23.8 % lower CO_2 emissions compared to the TAD. The potential impact of transitioning from a TAD to HAD on a population-wide scale is important. For instance, if half of the adult population were to adopt the HAD, not only would it meet nutritional targets [25], but would also lead to a substantial reduction in CO_2 emissions, estimated at approximately 2.6 billion kg annually [47]. To put this into perspective, this reduction is equivalent to the emissions of around 1.2 million passenger cars per year and would require over 256 million trees to offset the amount of CO_2e produced [48–50] (Item S1, Supplementary Materials). However, total costs for the HAD were 51.3 % higher than those for the TAD, suggesting that if convenient, ready-made options are prioritised, as they were in the present feeding trial, financial burden may be a significant barrier. These findings are not only relevant for future menu planning in clinical trials that provide food, but also have broader implications for individuals seeking to reduce their carbon footprint while adhering to current guidelines for heart-healthy eating. This is especially important for those with limited food preparation skills who rely on convenient dietary options.

In the current study, we observed that meat and discretionary foods made the largest contributions to CO_2e emissions in TAD, accounting for over 50 % of the overall footprint. Conversely, in HAD, discretionary foods were the lowest contributors, while dairy and vegetables emerged as the primary contributors due to the high recommended quantities. In the current analysis of individual food products, we found that cheese and beef products consistently ranked among the top three highest contributors to CO_2e across both dietary patterns. Conversely, oils and grains made minimal contributions to the overall CO_2e footprint for both patterns. These findings align with previous research, underscoring that diets rich in meat and dairy tend to have a higher carbon footprint compared to those rich in vegetables and legumes [51–56]. Similarly, other studies have also found that grains, despite being a staple in Australian diets and a major component of national dietary recommendations [29], contributed relatively less to carbon emissions [30]. This is likely influenced by specific foods found in higher quantities in HAD, such as rice, and due to how it is produced in Australia where high-yielding Australian rice varieties require less water and contribute to a negative climate impact unlike other varieties [30,32]. The present study infers that consumption of a climate-neutral diet for the Australian population is not currently possible without compromising nutrient quality in diets, which rely on convenience options.

The current findings contrast previous studies [57,58], which suggested that less-healthy diets containing more non-core foods such as sweets, snacks, fat, and oils, had a lower environmental impact. This difference is likely due to the various methodological approaches used to calculate the environmental impact, including the use of the GWP100 metric [57]. Some studies have used the GWP* metric, specifically within the Australian context, which supports the lower climate footprint of recommended/healthier Australian diets compared to typical diets [9,32,59]. However, slight differences even among these studies are likely due to variations in food and beverage selection within each food group, aimed at meeting the serving and nutrition recommendations, as well as the reference person and estimated nutritional requirements. For instance, the current study found that the current Australian diet for a 71-year-old male produced 2.83 kg CO_2e per day (with an EER of 2143 kcal), whereas Clay et al. [30] reported 2.38 kg CO_2e per day (EER of 2129 kcal), and Ridoutt et al. [32] calculated 3.1 kg CO_2e per day (EER of 2276 kcal) for a male aged 71 years or above, all using the GWP* metric. These data illustrate that dietary choices of specific foods within each food group can achieve small reductions in environmental impact. However, major reductions in the climate impact of diets will require substantial efforts from the agricultural and food processing industries [32].

Consideration of additional factors influencing consumer food choices, such as financial costs and convenience, is often overlooked in studies on dietary sustainability [60,61]. In Australia, there are marker inequalities in the affordability of a healthy and sustainable diet [62], with low-income households being more susceptible to diet-related chronic diseases [63]. Consequently, the recommended diet is often financially out of reach for those from lower socioeconomic groups [64–66]. Simultaneously, convenient options play a pivotal role in food selection in today's fast-paced world and amidst the evolving landscape of the contemporary food supply [67–69]. The current study demonstrates that it is possible to reduce the carbon footprint relative to typical dietary intakes while maintaining nutrient density and adherence to national dietary guidelines and accommodating the needs of individuals with limited cooking skills who may also be time-poor. However, this reduction comes with higher costs.

In our analysis, the largest expenses in HAD were associated with vegetables and fruits, as they comprised the largest portion of the diet, consistent with existing research [63,70,71]. Conversely, for TAD, discretionary foods and grains remained significant expenses, collectively contributing to a substantial portion of the overall cost. Research suggests that if convenience and reliance on ready-made meals were deprioritised, it would be feasible to achieve a healthy Australian diet up to 20 % cheaper than a typical Australian diet, depending on the geographical area [64–66]. Therefore, strategies aimed at lowering the costs of nutritious foods should be considered. Greater attention should be directed towards the long-term societal benefits and potential cost reductions associated with improved health outcomes and environmental preservation. This may involve implementing policies or creating systems embedded in our food supply, potentially achieved through innovative processes, which incentivise the reduction of costs in healthy foods that also have a lower carbon footprint. For example, if agriculture shifted towards more circular approaches and reduced its reliance on fossil fuels, it could significantly contribute to these goals. The use of precision agriculture may lead to more efficient planting, watering, and fertilisation, reducing waste and increasing yield, thereby lowering production costs. Encouraging local sourcing could reduce transportation costs and emissions, support local economies, and ensure fresher produce. Finally, food recovery programs could also reduce food waste and make healthy foods more affordable and accessible.

There are several strengths to this study. Firstly, it addresses a gap by examining the climate footprint of two distinct diets using the GWP* metric while also considering convenience, cost, and adherence to healthy eating guidelines. This holistic approach caters to individuals with limited cooking skills or those seeking ready-made meals, ensuring a broader applicability of the findings. All multi-ingredient foods and mixed dishes in the meal plans were dissected into individual ingredients, allowing a more precise assessment of their environmental footprint. However, limitations arise from the database's limited food options, requiring substitutions that could affect the accuracy of CO_2 emission estimates. Disaggregating foods into basic ingredient components also introduces subjectivity, potentially resulting in the under- or over-estimation of the true CO_2 emission impact. However, the same standardised approach was applied to both diets, allowing for a similar approach to comparisons. Our study modelled diets for 34 healthy Australian adults, encompassing diverse demographics, despite the small sample size. However, the resulting diet plans may not be applicable to individuals with specific medical conditions, unique food preferences, or dietary restrictions, given that our participants were generally healthy and willing to consume the foods provided, potentially reducing the external applicability of the findings. This study also employed the GWP* metric, which is considered the best metric available for assessment of the dietary footprint due to accurate inclusion of short-lived pollutants, e.g., methane [12,16,72]. The metric indicates the effect of long and short-term GHG on temperatures, providing a more comprehensive assessment of the dietary footprints. However, this choice limits direct comparisons with other studies, which have often relied on the GWP_{100} metric [9,10]. Nevertheless, the GWP* calculator does not include factors such as land change, food loss, waste, or CO_2 emissions from packaging and food preparation, potentially underestimating total CO_2 emissions. Likewise, although the food groupings primarily align with Australian Dietary Guidelines [29], further clarification of alternative protein sources such as legumes that can be grouped in vegetables or meat and alternatives, may improve the representation of their varying environmental impacts. However, this may also affect the direct comparisons with other studies. Finally, the affordability was assessed through a fortnightly food basket from a major supermarket, adjusted for promotional prices to reflect real-world grocery shopping practices. However, these costs would fluctuate depending on price promotions and seasonal availability of products. Therefore, direct comparability of results to other dietary patterns is limited as this analysis represents one snapshot in time. Thus, interpretation of these results must be approached with caution.

5. Conclusion

The current study indicates that a HAD is not only better for human health from a nutrition and disease prevention perspective, but also has a lower environmental footprint. A population shift from TAD to a HAD dietary pattern could have substantial benefits. The major barrier is likely affordability of this type of dietary pattern, particularly in the context of people trying to achieve this using convenience foods. Therefore, creating incentives, policies or systems that can intervene and reduce costs is going to have a widespread benefit. Additionally, the current study presents valuable information for future trials where a HAD can easily be implemented by individuals. Even though climate neutrality of dietary patterns remains elusive in the current Australian food systems, the footprint can be reduced substantially through the promotion of healthier food choices. In future studies, expansion of the GWP* database is needed to accurately and comprehensively assess CO_2e impact. Moreover, additional environmental dimensions such as water scarcity, land use, food losses and biodiversity should be considered.

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CRediT authorship contribution statement

Rachel E. Cobben: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Clare E. Collins:** Writing – review & editing, Conceptualization. **Karen E. Charlton:** Writing – review & editing, Methodology, Investigation. **Tamara Bucher:** Writing – review & editing, Methodology, Investigation. **Jordan Stanford:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation.

Declaration of competing interest

All authors declare no conflicts of interest with regard to the research, authorship and publication of this article.

Data availability

All data is available from the included manuscripts, further information can be requested from the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ahjo.2024.100448.

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