Nutrition & Dietetics
Journal of Dietitians Australia
Volume 80 Number 1 February 2023

Food, nutrition and health

Dietitians Australia
WILEY

Nutrition & Dietetics

Journal of Dietitians Australia

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NDI.JEB.Feb23

Nutrition & Dietetics

Journal of Dietitians Australia

Volume 80 Number 1 February 2023 **ISSN 1446-6368**

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DOI: 10.1111/1747-0080.12798

EDITORIAL

Nutrition & Dietetics Journal of Dietitians Australia WILEY

The United Nations Sustainable Development Goals: Aspirational or obtainable?

The 2015 United Nations' Sustainable Development Goals set out to ignite political agendas across the world to improve the human condition.[1] A year later, the World Health Organization and the Food and Agricultural Organization of the United Nations declared the 10-year period to 2026 as 'the decade of action on nutrition'.[2] These influential bodies have provided goals and frameworks to stimulate political, social, environmental and economic solutions with some pertinent goals centred around food and nutrition, to reduce poverty, hunger and under-nutrition as well as reduce premature mortality from non-communicable diseases.

Supporting the Australian response and to focus attention on achieving Sustainable Development Goal 2 'Zero hunger' and Sustainable Development Goal 3 'Good health and wellbeing', the Australian Academy of Science, via its National Committee for Nutrition, auspiced the co-creation of a decadal plan for the science of nutrition.[3] In 2017, 60 mid-career researchers, including many dietitians, were brought together in a Theo Murphy 'Think Tank' to envision the future of nutrition. The output from this 'Think Tank' provided the fundamental concepts of the Australian decadal plan for nutrition, which was socialised in 2018 and launched in Parliament House in mid-2019. Entitled 'Nourishing Australia: a decadal plan for the science of nutrition', the stated vision is that 'Australian nutrition science plays a key role in improving long term health and wellbeing globally while delivering environmental, social and economic benefits nationally with core values of equity, sustainability, collaboration and innovation'[3]

'Nourishing Australia' assists in contextualising Sustainable Development Goal 2 and Sustainable Development Goal 3 and, if Australia is to come close to achieving these currently aspirational goals, it will require concerted effort, a unilateral commitment and multi-sectorial action.[3] As such, it provides a focused advocacy document and road map that can be utilised to advocate for change within Australian nutrition science and the food system with several priority areas for action identified. The need for further investment in nutrition and food research is clearly stated including the translation of that research into practice and systems change. This need is supported by the Australian Bureau of Statistics' reporting that the majority of Australian adults are above a healthy weight, 1 in 20 have diabetes, and 6.1% consume the recommended quantity of fruit and vegetables.[4–6] These sobering figures suggest that there is not only a need for improved and better access to effective treatment for those with non-communicable health conditions, but the imperative to focus on the prevention of diet-related conditions via supporting a more robust food system and addressing inequity in both access and availability of health-promoting food.

The profession of nutrition and dietetics is well placed to deliver on the Decadal Plan areas of action, but how are we to improve our leverage to gain a greater proportion of research and health investment dollars for nutrition and dietetics research? To ensure that, we have elucidated priority areas for dietetics research, whereby an expert panel consensus process was used to prioritise areas of need for 2020–2030 and reported by Porter *et al.*[7] This consensus document provides a new definition of dietetics research, embracing both its scope and diversity across the multiple systems and settings where dietitians work. A thematic approach to priority research areas included (i) the need to achieve a balance between prevention and treatment approaches, (ii) support for healthy ageing, (iii) for vulnerable populations, (iv) for food systems and health promotion, and finally (v) newer areas such as informatics. Interestingly, the need to focus on personalised nutrition was not seen as a current priority area for dietetics research despite it being seen as an underpinning pillar of knowledge in the Decadal Plan.[3]

So, what progress has Australia made towards the Sustainable Development Goals? There is no doubt that implementation has been severely impacted by the COVID-19 pandemic. COVID-19 has left no one untouched, with the worldwide public health responses leading to rapid changes both in home and work environments. Arguably, the pandemic responses have had some positive impacts, such as accelerated practice changes, such as the adoption of telehealth, virtual conferences and online learning which are acknowledged as useful substitutes to traditional face-to-face meetings,to augment and promote connection and broaden access to

professional development opportunities previously limited by geography and/or cost.

Pandemic responses have educated the public as to how epidemiological data can be applied to policy; we have had demonstrations on how epidemiology can be communicated to the public as previously unheard-of public health officials have become media stars. We now have the lived experience of public health interventions to an extent never previously implemented at a whole population level. As we start 2023, we are emerging differently, more focused on the 'big' issues that have been amplified since the pandemic closed our borders such as food security and hopefully, we emerge more determined to drive the systems to change that which is required to achieve Sustainable Development Goal 2.

The 'pandemic years' have been both a time of introspection and future visioning for nutrition and dietetics. Peak bodies such as the Council of Deans of Nutrition and Dietetics (https://www.deansnutritiondietetics.com) released the Future Dietitian Report in 2021.[8] The qualitative methodology employed in this seminal report sought deep insight from multiple perspectives as to how the nutrition and dietetics profession may look by 2030. The outcomes supported six roles for the profession of nutrition and dietetics in the future: (i) as food aficionados, (ii) as diet optimisers, (iii) as knowledge translators, (iv) as champions of equity, (v) as systems navigators and food systems activists and finally, (vi) as change makers, activists and disruptors. All these roles are desperately needed if Australia is to make faster progress towards the Sustainable Development Goals. One of the five priority actions in this future visioning report to strengthen the profession of dietetics, was the need to ensure nutrition science was the backbone of education with an integration of systems elements to build the capability to impact change.

The diversity of practice in nutrition and dietetics that our profession is involved with is exemplified by the topics that comprise this issue of *Nutrition & Dietetics*. Indeed, the first issue of 2023 provides content that would align with many of the goals of the Decadal Plan[3] and demonstrates the roles that our profession has developed and will continue to develop.

Hoare *et al*. review the impact of weight-neutral interventions and describe the potential for this emerging area of practice approach to be useful for adolescents who present with co-morbidities such as obesity and eating disorders or with anxiety and or depression.[9] Blumfield *et al*. focus on Indigenous adolescents, drawing data from the 2012 to 2013 National Aboriginal and Torres Strait Islander Nutrition and Physical Activity Survey to explore the relationships between dietary intake, weight status and body image in relation to habitation based on geographical remoteness.[10] This analysis highlights the interwoven relationships between food and nutrition outcomes with issues such as body image perception, weight-related behaviours, and food consumption at a developmental life stage that will impact an individual's trajectory towards non-communicable diseases as well as the substantial nutritional vulnerability of Indigenous adolescents.

Waddington *et al*. explores the state of the evidence for dietary patterns in those undergoing replacement therapy for opioid addiction, concluding that there is clear evidence of irregular food intake with resultant risks of macro- and micro-nutrient deficits.[11] These findings support the need for increased funding for practice-based nutrition research for this vulnerable group.

These papers collectively demonstrate the need for nutrition and dietetics professionals working with different vulnerable communities to be champions for equity, have skills for not only improving the food supply, but equipped with a range of behaviour change strategies to address physical and mental health concerns of various 'at nutritional risk' populations.

Further focus on the food supply is provided in this issue via a cross-sectional survey of fruit and vegetable consumption from a convenience sample of adults living in New South Wales.[12] Only 12% of respondents met vegetable serve recommendations despite many participants believing their intake was adequate. This disparity between 'actual' and 'perceived' intake suggests that we need to substantially improve engagement with consumers to influence their actual behaviour if we are to be effective 'diet optimisers'. We surely need to increase the proportion of the population who are going to reap the health rewards of a dietary pattern more aligned with a reduction in non-communicable diseases.

The microbiome and its role in the cross-talk between the gut and the brain alongside its relationship with immunity and even our mental health is a hot topic in nutrition science. In this edition, consumer perspectives in relation to gut health are examined using a qualitative methodology that makes interesting reading in terms of how consumers perceive health advice and dietary guidelines and how they interpret those alongside the voices of commercial products and the competing interests of commercial companies.[13] Reflection on the findings of this paper supports the need for a 'trusted voice' with consumer-facing messaging to reduce their scepticism and barriers towards dietary guidelines. On a similar theme but exploring how dietitians perceive their role in gut health, is the second paper by Williams *et al*.[14] This paper reports the need for dietitians to have greater access to evidence-based data augmented with evidence of how to successfully translate this into practice to improve their

confidence in being able to assist their clients. The commitment by dietitians to evidence-based practice is very clear, but how to maintain currency of knowledge in a rapidly evolving and complicated area of nutrition science is a challenge.

Also in this issue, the role of dietitians in medical nutrition therapy is exemplified by Bendall and Taylor,[15] who systematically review the literature to explore the relative benefit of oral versus nasogastric feeding for those hospitalised with malnutrition resulting from restrictive eating. A lack of clear difference in weight gain between the two methods of refeeding and with those selected for nasogastric feeding being admitted to the hospital with a lower starting body weight made it challenging to determine with any certainty that one method is superior to the other.

In a review examining the association between dietary patterns, diet quality, and food groups in adults with symptomatic osteoarthritis, Das *et al*. reports the generally low quality of evidence in this area, mainly drawing evidence from cohort studies.[16] However, poor diet quality was associated with the progression to the painful symptoms of osteoarthritis. This review concludes that being able to incorporate previously unstudied dietary patterns and food groups may elucidate beneficial impacts for those who suffer from this chronic and painful condition.

The 'Nourishing Australia' Decadal Plan proposes two platforms to support many of its goals:[3] the need for new national infrastructure to collate data from many different sources to inform and progress evidence-based actions and systems changes. The Decadal Plan proposes the development of a food and nutrition 'knowledge hub'. This new national capability would have the ability to integrate food intake data along with health outcomes, which can be interrogated to produce evidence, and which would inform national policy and public health intervention strategies. A clear example of the benefits of such a 'big-data' capability would be to interrogate very large datasets combined with relevant health outcomes to elucidate diet–disease relationships for Australians with chronic health conditions.

Analysis arising from this knowledge hub would provide evidence-based information that would be translated by professional bodies and communicators applying contemporary modes of communication as a 'trusted voice'. This 'trusted voice' provides a credible, reliable and collective source of consistent advice to the government to influence policy and inform their planning, and also - crucially important but taking a different approach - a voice to the general public. The concept model of the public-facing 'trusted voice' is that it will engage in meaningful dialogue with the public to re-build their trust in health professionals, improve their nutrition literacy, and their ability to differentiate between evidence and non-evidence-based food and diet advice.

As we welcome 2023, a year when our news may not be dominated by COVID-19, let us review progress towards implementation of the Decadal Plan and towards achievement of Sustainable Development Goals. There have already been steps forward. A focused workshop facilitated by the National Committee for Nutrition relating to the need for a nutrition data hub ignited the interest of the Australian Research Data Commons who initiated their food program with a focus on how data may offer potential solutions to improve Australia's food security.[17] Food systems and supply chains have been brought into sharp focus recently—highlighting the lack of resilience of the Australian food supply, its vulnerability to environmental impacts, such as national disasters caused by fire, floods and pandemics plus logistical supply chains that are easily disrupted by political unrest alongside labour shortages.

Developing a formal implementation plan for the Decadal Plan is now a focus of the National Committee for Nutrition.[18] The Australian Academy of Science will evolve its governance structure to support a new nutrition implementation committee with representation from all peak bodies with an interest in nutrition and food in Australia. Dietitians Australia is a key participant on the National Committee for Nutrition and a major stakeholder in the new Implementation Committee, in particular delivering on the concept design of a 'trusted voice'.

A further Theo Murphy Think Tank is planned for 2023: this will bring together the nutrition and dietetics community to co-design an implementation framework for the Decadal Plan. This will be followed by a Boden Conference focused on Personalised and Precision Nutrition in Canberra on the 18th and 19th of October 2023.

So, can Australia achieve Sustainable Development Goal 2 and Sustainable Development Goal 3? Do we have the commitment and road map? Yes, we do. There is no doubt that it will need strong, collective, intersectoral action with consistent commitment and collaboration from nutrition and dietetics professionals to advocate for the necessary systems changes. We need to be the change makers, activists and disruptors as envisioned by Future Dietitian 2030.[8]

The words of Charles Darwin are pertinent in this context 'It's not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change'. As we are now well into the second half of the decade of action on nutrition, there is much to do, but

our profession will not only survive, it will thrive, as we not only reimagine the future, we lead it.

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Received: 16 October 2021 | Revised: 9 January 2022 | Accepted: 24 January 2022

DOI: 10.1111/1747-0080.12729

Nutrition & Dietetics Journal of Dietitians Australia WILEY

REVIEW

Weight-neutral interventions in young people with high body mass index: A systematic review

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Funding information
Johanna K. Hoare was supported by a University of Sydney scholarship. Natalie B. Lister was supported by a National Health and Medical Research Council Peter Doherty Early Career Fellowship. Hiba Jebeile was supported by the Sydney Medical School Foundation (The University of Sydney).

Abstract

Aim: This systematic review explored the feasibility, acceptability and effect on health outcomes of weight-neutral interventions in health improvement-seeking young people with overweight/obesity.

Methods: Six databases were searched to March 2021 for health, but not weight, focused interventions (PROSPERO, CRD42020152671). Eligible studies recruited young people (10–24 years) with overweight/obesity. The studies were described using narrative synthesis, with numerical results summarised. The quality of included studies was assessed using the Joanna Briggs Institute critical appraisal tools.

Results: Six articles were included, representing three pilot studies. Study 1 ($n = 37$, 14–17 years) compared a 6-week mindful eating program with single-session lifestyle education; Study 2 ($n = 35$, 14–17 years) compared 12-week weight-neutral lifestyle education focused on intuitive eating and carbohydrate quality, with/without guided imagery; and Study 3 ($n = 33$, 12–17 years) compared a 6-week mindfulness intervention with cognitive behavioural therapy in adolescents with depressive symptoms at risk of type 2 diabetes. All interventions explored feasibility (intervention group retention 57%–88%, attendance >80%) and reported interventions were acceptable. Studies 1 and 3 reported no change in mindfulness. Study 2 reported an increase ($p < 0.05$) in intuitive eating following weight-neutral plus guided imagery (0.32 ± 0.36, Hawks' Scale, score 1–4), compared with weight-neutral alone (0.15 ± 0.29). Study 1 reported decreased body mass index ($p < 0.001$) following mindful eating (-1.1 kg/m^2), compared with single-session lifestyle education ($+0.7$ kg/m^2); Studies 2 and 3 found no change in body mass index or body mass index z-score.

Conclusions: Weight-neutral interventions may be feasible and acceptable in adolescents with overweight/obesity in the short term (≤12 weeks), but data are limited.

KEYWORDS

adolescent, body weight, health at every size, mindfulness, obesity, overweight

1 | INTRODUCTION

Obesity in young people increases the lifetime risk of health adversity.[1] The weight-neutral model of health (Box 1) is an emerging area of clinical practice in adults, proposed as an alternative to conventional weight management in adolescents.[6] In this review, we use a generic term *weight-neutral approaches* to describe practices that aim to support non-weight related behavioural, psychological and/or metabolic health outcomes.[2,7] Components of weight-neutral approaches may include mindful and/or intuitive eating, mindfulness, meditation, body acceptance, movement for enjoyment, and/or healthy eating patterns focused on nourishing foods instead of energy density or portion control.[2,8–10] A variety of terms appear in the literature to signify these approaches, including Health at Every Size (HAES®),[11] mindful/intuitive eating,[12] size acceptance,[10] non-diet,[13] and health not weight loss[14] (Box 1). A common concept in weight-neutral approaches is to reduce weight-related stigma and feelings of guilt or shame related to eating and personal appearance.[15]

Weight-neutral interventions in adults have been compared with conventional weight management approaches in two systematic reviews and meta-analyses.[4,14] These reviews included nine[4] and eight[14] studies, with an overlap of four studies.[10,16–19] Meta-analyses of randomised controlled trials (RCTs) showed no between-group differences in weight-related or cardiometabolic outcomes, diet quality, physical activity and most psychosocial and behavioural outcomes.[4,14] In the review by Dugmore et al., the weight-neutral groups demonstrated a statistically significant improvement post-intervention in the bulimia subscale of the Eating Disorder Inventory in two studies, compared with conventional weight management interventions.[4] In the Dugmore review, a subgroup analysis of long-term (≥1 year) studies showed no between-group differences for any of the outcomes, with the bulimia subscale reported by a single study[10] involving a long-term follow-up. A separate 2021 systematic review of RCTs (13 studies) reported mixed findings on diet quality from mindful and intuitive eating interventions in adults with or above a healthy weight.[12] The majority of the studies in this review[12] reported no between-group difference between mindful and intuitive eating and controls assigned to non-treatment,[20–22] waitlist,[23–25] conventional weight management,[17] and dietary self-management of type 2 diabetes.[26] Three studies favoured the mindful eating intervention,[27–29] and one study favoured nutrition-focused diabetes self-management education over mindful eating.[30] One limitation of the adult literature is that studies have predominantly been conducted in White female individuals aged ≥40 years. The feasibility, acceptability and effectiveness of weight-neutral approaches in younger and culturally diverse populations are therefore not known.

The high prevalence of obesity and the increasing incidence of more severe obesity[31] in young people continues to present a global health challenge.[32] While multi-component lifestyle interventions remain the first-line treatment for young people with overweight and obesity, the provision of a range of population-specific evidence-based treatment approaches is vital.[33,34] Life transitions and major developmental changes may contribute to young people responding to interventions differently from adults.[35,36] Hence, treatment options designed specifically for young people may enhance clinical outcomes through improved acceptability, recruitment, retention, therapeutic compliance, and/or participant skills.[37–41] Adolescents have also reported preferring intervention messaging that emphasises health improvement over weight focus.[41] Given the vulnerability of young people with obesity to psychosocial adversity[42,43] and weight stigma/victimisation,[44] weight-neutral interventions encompassing emotional wellbeing warrant investigation.

To our knowledge, however, there has been no systematic review addressing weight-neutral health interventions in young people. This review aimed, first, to explore the feasibility and acceptability of weight-neutral interventions in young people aged 10 to 24 years with overweight or obesity, and, second, to collate the results from the interventions on physiological, cardiometabolic, behavioural and psychosocial outcomes.

BOX 1 Weight-neutral paradigm

- Holistic approach promoting health and diet quality, with no focus on body weight[2,3]
- Aims to improve physical and psychosocial well-being and quality of life, and promote a healthy relationship with food[4,5]
- Key concepts: self-acceptance, body weight/shape/size acceptance, reduction of weight-related stigma[2,4]

2 | METHODS

Details of the protocol for this systematic review were registered on PROSPERO International prospective register of systematic reviews (CRD42020152671). This review was reported using the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[45,46]

Intervention studies recruiting health improvement-seeking young people (defined by the World Health Organization[47] as ages 10 to 24 years) with overweight and obesity, defined as body mass index (BMI) above a healthy weight; BMI z-score (BMIz) >1; clinical diagnosis of overweight or obesity; or study population reported as being above a healthy weight, were identified. Studies including broader age ranges were included if the results were reported separately for our specified age range, or if the mean age of the participants fell within this range. Studies were excluded if they recruited participants within a healthy weight range, to ensure included interventions were those which were specifically tailored to young people with overweight or obesity.

Studies eligible for inclusion were original research interventions aiming to improve, and reporting on, weight-related physiological, cardiometabolic, behavioural, and/or psychosocial outcomes or health risk factors. Interventions were included if they implemented weight-neutral approaches (Box 1) including, but not limited to, mindfulness, mindful/intuitive eating and body acceptance. The studies did not have to self-identify as weight-neutral. Anthropometric variables could be measured, reported and discussed for research purposes, provided the program aims and approaches communicated to participants were not related to weight loss, body size or body weight. Eligible studies were RCTs, quasi-experimental interventions, pre-post studies, feasibility trials, and case studies conducted in a broad range of settings such as educational institutions, community, hospitals and online. No limitation was placed on intervention duration or sample size.

Excluded studies were systematic reviews, meta-analyses, cross-sectional and longitudinal observational studies; interventions treating eating disorders, specific diseases or health behaviours unrelated to body weight; studies designed for weight loss (allowing for unintentional weight loss or BMIz reduction, if this was measured, during a weight-neutral intervention); and studies treating overweight or obesity through pharmacological or surgical approaches. Interventions targeting non-treatment seeking populations, such as school or community-based health education, obesity prevention or health promotion programs were also excluded. Furthermore, studies were not eligible if the participants were pregnant, or had secondary or syndromic causes of obesity. Studies were also excluded if the full text was not available.

Electronic databases Medline (via Ovid), Embase (Excerpta Medica Database, via Ovid), CENTRAL (the Cochrane Central Register of Controlled Trials), PsycINFO (via Ovid), Scopus, and CINAHL (Cumulative Index of Nursing and Allied Health Literature) were searched from inception to 17 March 2021 for articles published in English. The search strategy was determined for Medline and adapted for the syntax and controlled vocabulary of the other databases (Online Supplementary File: Appendix A). The truncated search terms and keywords were extended with adjacency searches and were related to adolescents and young adults; weight, overweight, and obesity; and interventions informed by weight-neutral approaches. Additional hand searching was performed based on the reference lists of relevant publications, and studies citing key research.

Following the removal of duplicate records using EndNote X9 software (Clarivate Analytics, U.S.), the citations were extracted, and the title/abstract screening and full-text review were performed by two researchers independently using Covidence® online software (Veritas Health Innovation Ltd). Disagreements were resolved through discussion.

From included studies, data were extracted into summary tables by one reviewer and checked for accuracy by a second reviewer. Extracted data included study characteristics such as study design and settings; population demographics and sample size; intervention characteristics such as study duration, period of follow-up, study arms and comparators; equipment and tools used in outcome data collection; and data on health-related study outcomes. The authors were contacted for additional information regarding adjustment criteria for baseline data[48] and the scoring of a validated instrument.[49]

The methodological quality of the included articles was independently determined by two reviewers using Joanna Briggs Institute critical appraisal checklist for RCTs.[50,51] Each study was assigned an overall classification of include, exclude, or seek further information. Conflicts were resolved through discussion.

The characteristics and results of the included studies were described using narrative synthesis, and numerical results were summarised. All measurement units were converted to SI units. Due to the limited number of studies, small sample sizes, and heterogeneity in intervention characteristics and outcome measures, a meta-analysis was not performed.

3 | RESULTS

Of 3819 records identified in the literature search, six articles were included[48,49,52–55] representing three separate studies (Figure 1). One article described the full intervention to the 6-month follow-up,[48] with additional

publications reporting the 1-year follow-up[54] and a case study[52] (data included in the main publication). Another article was a dissertation[53] with a subsequent journal publication describing the intervention.[49]

Characteristics of included studies are summarised in Table 1. The three included studies were short-term pilot studies designed to explore the feasibility and/or acceptability, and the effect of the weight-neutral intervention in adolescents. The number of participants in each study ranged from 33 to 37, with ages from 12 to 17 years. Baseline BMI ranged from 29.2 to 37.7 kg/m^2. Additionally, one study each reported a baseline value for BMIz (range from 2.23 to 2.30[55]) and BMI percentile (range from 92.75 to 94.94[48]). Participants were informed of the intervention aims, which were to study the effect of mindful eating[49,53] and guided imagery,[55] and to reduce their type 2 diabetes risk.[48] Recruitment was conducted from healthcare settings,[55] a school,[49] and through a combination of direct/online advertising and flyer distribution through schools and doctors.[48] One study (n = 35) reported not reaching its recruitment target of 40 participants due to time constraints,[55] and a school-based study[49,53] reported initially slow enrolment although later reaching capacity. This study reported 43% post-randomisation withdrawals following the introductory session.[53]

Body weight and height were measured and BMI percentile[61] was calculated in all included interventions to determine eligibility to participate, but not to encourage weight loss. In one study, anthropometric variables were also used as covariates to adjust outcome measures.[48] The interventions were based on mindfulness[48,49] and intuitive eating,[55] and reported on a range of outcomes (Table 1) including anthropometry and body composition (BMI,[49,54,55] BMIz,[54,55] body fat percentage[48,54]), behavioural (dietary intake, physical activity)[55] and psychosocial variables (mindfulness,[48,49,54] intuitive eating,[55] stress,[48,54,55] depression,[48,54] anxiety[48,54]), and the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR).[48,54,55]

Study 1, Mindful Eating and Living, was a 6-week, school-based pilot study[49,53] exploring the effects of mindful eating on BMI and mindfulness. Eligible participants (n = 37 Latina females, aged 14 to 17 years, BMI >90th percentile) were randomised 1:2 to the experimental and comparator conditions. In weekly sessions following the satiety-focused Mindful Eating and Living curriculum,[53,62] the intervention group explored their motivations to eat and practised mindful eating (slow intentional eating while observing satiety signals). The non-treatment comparator group attended the introduction and measurement sessions only.[49] Both groups received the same written nutrition and exercise information.

Study 2, the Imagine Healthy Eating Active Living Total Health (Imagine H.E.A.L.T.H.) lifestyle program[55] was a 12-week randomised controlled pilot study recruiting Latino adolescents with obesity (n = 35, 14 to 17 years, BMI >95th percentile). It aimed to evaluate the effects of Interactive Guided Imagery^{SM}, over and above weight-neutral lifestyle education alone, on insulin response, stress, physical activity, dietary intake and diet behaviours such as intuitive eating. The intervention delivered the same weight-neutral lifestyle education to all participants, encompassing intuitive eating, nutrition education focusing on dietary carbohydrate modification, and active living. The experimental group additionally participated in guided imagery sessions, while the remaining study participants were exposed to an unrelated control condition (digital storytelling) of equivalent intensity.[55] The pilot program contained no post-intervention follow-up.

Interactive guided imagery is a facilitator-guided technique aiming to increase the participant's autonomy using metaphors. A subjective image related to a particular topic is visualised, and its meaning is explored through a dialogue with the image.[63] For example, in the stress reduction sessions the participants were asked to visualise a 'relaxed place' while engaging in breathing and relaxation exercises. Other sessions, focused on healthy eating and active lifestyle, included the participants visualising images of hunger and fullness, imagining themselves practising healthy behaviours, and engaging in a dialogue with an 'Inner Advisor' educating and motivating them to trial these changes, and an 'Inner Warrior' to improve self-efficacy. The final sessions focused on visualising one's future self after lifestyle modification.

Study 3, a mindfulness group intervention,[48] was a 6-week randomised controlled pilot study with 1-year follow-up,[52,54] based on the Learning to BREATHE curriculum designed for adolescents.[64] Mindfulness promotes consciousness in the present, and observing one's environment in a non-reactive and non-judgmental manner.[65] The study recruited female adolescents from diverse ethnic backgrounds (White, Hispanic, Native American/American Indian) with overweight and obesity (n = 33, 12 to 17 years, BMI ≥85th percentile) with mild/moderate symptoms of depression and an elevated risk for developing type 2 diabetes, based on family history. The aim was to compare the efficacy of a mindfulness-based group intervention with cognitive behaviour therapy in reducing depressive symptoms and improving insulin response. The control group participated in the structurally equivalent cognitive behavioural therapy depression prevention program Colorado Blues that delivered psychoeducation and cognitive restructuring, and promoted behaviour change, self-efficacy, and coping skills.[48]

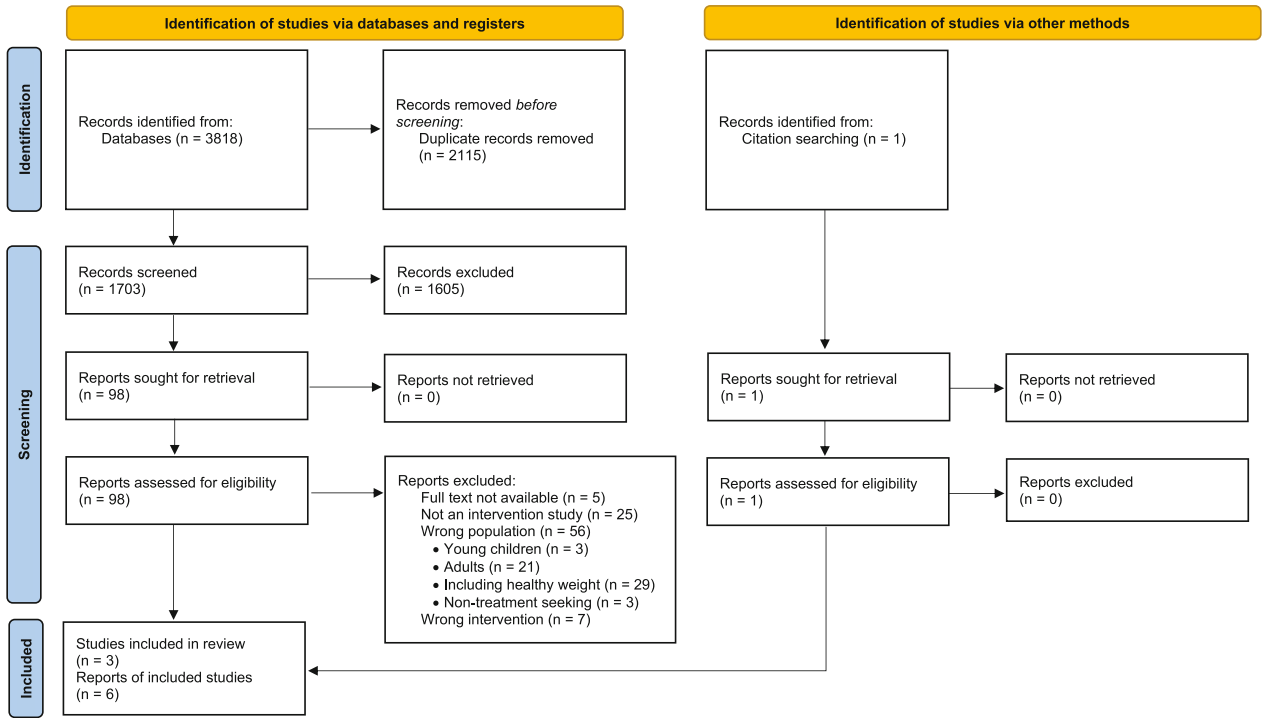

FIGURE 1 Preferred reporting items for systematic reviews and meta-analyses flow diagram

All included studies examined intervention feasibility and acceptability. Feasibility was assessed from program retention,[49] session attendance[48,49,55] and/or completion of assigned homework[48] (Table 1). Post-intervention retention of participants was lower in the treatment groups, compared with controls (Table 1). Across the 6-week interventions, the treatment groups retained 8 of 14 (57%)[49] and 13 of 17 (76%)[48] participants. In comparison, the active control and single session comparator groups retained 15 of 16 (94%)[48] and 15 of 23 (65%)[49] participants, respectively. In the 12-week intervention where both groups received the core weight-neutral lifestyle education component, the number of retained participants was 15 of 19 (79%) in the group participating in the guided imagery, and 14 of 16 (88%) in the comparator.[55] At longest follow-up (Study 3, 12 months), the retention was 71% in the intervention group and 81% in the controls.[54] A pre-set target for attendance was either not specified[55] or set at ≥80%.[48,49] The attendance rates exceeded 80% among retained participants in all experimental[48,49,55] and active control[48] arms (Table 1). Study 2, implementing informal assessment of homework completion, described very low levels of home practice,[55] while Study 3, reviewing homework completion to assess program feasibility, reported completion of ≥75% of assigned homework following most sessions.[48]

Program acceptability was evaluated from individual surveys during the intervention,[55] post-intervention surveys,[48,49] group interviews,[49] and focus groups.[55] One study[49] was delivered by a single interventionist (not reported whether the same person collected the acceptability data), with the two other studies[48,55] not reporting who conducted the in-person acceptability evaluations. Participants self-reported improved mood,[48] reduced stress,[55] and increased ability to identify and implement strategies to control their eating.[49,55] In one study evaluation the participants identified yoga, eating practice, and social support as the most useful enablers for behaviour change, articulating few challenges or suggestions for improvement.[49] The acceptability ratings showed no difference between groups in the only study with an active control arm.[48]

Several health outcomes were measured with few differences reported, noting the studies were underpowered to detect significant differences between groups. Dispositional mindfulness did not change significantly within groups post-intervention (Study 1[49]) or between groups at any time to 1-year follow-up (Study 3[48,54]). Intuitive eating (Study 2[55]; total score, and subscales extrinsic eating and self-care) increased significantly post-intervention following guided imagery, compared with weight-neutral lifestyle education alone (Table 1). There was a significant difference in BMI change between groups in one study (Study 1, independent samples t-test, $p < 0.001$), with a decrease ($p = 0.019$) in the mindful eating group post-intervention and at follow-up (−1.1 and −1.4 kg/m^2 at 6 and 10 weeks from baseline, respectively) and an

TABLE 1 Study characteristics and outcomes

Author (year); Country Program name; Study design; Program setting Risk of bias	Baseline data: Sample size (*n*), %F Inclusion criteria Mean age (y) ± SD; BMIz/BMI/BMI percentile (mean ± SD)	Intervention duration; Period of follow-up from baseline *n* enrolled; Retention (R) post-intervention, (R) follow-up	Description of intervention/comparator Key weight-neutral concepts (K) Personnel (P) delivering the intervention	Outcome measurement (evaluation criteria/instruments used) Study findings Change in outcomes, mean ± SD
Study 1 Daly[53] (2013) & Daly et al.[49] (2016); USA Mindful eating intervention; RCT; after-school program in a public high school in a Latino community 54% of JBI	$n = 37$; 100% F Latina females 14 to 17 years, BMI >90th percentile **IG:** 15.4 ± 1.4 years; BMI 37.7 ± 7.6 kg/m^2 **CG:** 15.6 ± 0.9 years; BMI 34.3 ± 6.2 kg/m^2	6 weeks; 10 weeks **IG:** $n = 14$; Post R = 57%, FU R = 57% **CG:** $n = 23$; Post R = 65%, FU R = n/a	**IG:** Introductory session with baseline measurements. Weekly 90-min after-school group sessions with mindfulness meditation, nutrition and exercise, motivations linked to eating behaviours, mindful eating (eye, nose, mouth, heart, stomach, mental and cellular hunger), eating skills and satiety awareness practice. **CG:** Single, introductory session with study information, baseline measurements and a handout of nutrition and exercise information **K:** mindful eating, mindfulness **P:** principal investigator (author, single interventionist)	**Feasibility** (retention ≥55%, attendance ≥80%): Retained IG participants attended 100% of sessions **Acceptability** (short written responses, structured group interview): No challenges or suggestions for improvement were articulated. Participants reported improved ability to identify and implement enablers for gaining/maintaining control of eating. **Dispositional mindfulness** (adapted Mindful Attention Awareness Scale[56] [MAAS, 14-item, aggregate score 14–84]): **-IG:** BL 52.9 ± 12.8; post 56.1 ± 15.3 (ns) **-CG:** BL 58.1 ± 12.7, post 57 ± 16.4 (ns) **BMI** (kg/m^2): **-IG:** BL-post −1.1 ± 1.0*, FU −1.4* **-CG:** BL-post +0.72 ± 0.75* - Between-group difference $p < 0.001$
Study 2 Weigensberg et al.[55] (2014); USA Imagine H.E.A.L.T.H. (Healthy Eating Active Living Total Health); RCT; university clinic 69% of JBI	$n = 35$; 52% F Latino youth 14 to 17 years, BMI >95th percentile **IG(GI):** 15.5 ± 1.0 years; BMI 36.2 ± 5.9 kg/m^2; BMIz 2.30 ± 0.4 **IG(DS):** 16.1 ± 0.95 years; BMI 35.1 ± 4.6 kg/m^2; BMIz 2.23 ± 0.22	12 weeks; n/a **IG(GI):** $n = 19$; Post R = 79% **IG(DS):** $n = 16$; Post R = 88%	Weekly 45-min lifestyle group education on intuitive eating, healthy diet (incl. reduction of dietary CHO) and PA. Lifestyle sessions coupled with 45-min one-on-one sessions with: **IG(GI):** Interactive Guided Imagery sessions (stress mgmt, PA, healthy eating, barriers to change), or **IG(DS):** digital storytelling, digital media skills to create a story of a chosen topic (unrelated to obesity) **K:** intuitive eating **P:** Physical exam: licensed paediatric care provider; baseline measurements: nursing staff; lifestyle program delivery: trained health educator staff; guided imagery: certified IGI practitioners; DS: trained project staff; PA: personal trainer. Food diary instruction: trained staff	**Feasibility** (attendance): 90%–100% of all sessions for both groups **Acceptability** (subjective evaluation surveys during intervention, focus groups post-intervention): 90%–100% rating for all parts of the intervention for both groups despite low level of completion of homework in IG(GI) **Intuitive eating** (total score) (Hawks' Intuitive Eating Scale[57] [27-item Likert, average score 1–4]): **-IG(GI):** BL-post 0.32 ± 0.36* **-IG(DS):** BL-post 0.15 ± 0.29 **BMI** (kg/m^2): **-IG(GI):** BL-post 0.77 ± 1.18 (ns) **-IG(DS):** BL-post 0.16 ± 1.37 (ns) **BMIz** (SD): **-IG(GI):** BL 2.30 ± 0.4, BL-post 0.04 ± 0.09 **-IG(DS):** BL 2.23 ± 0.22, BL-post −0.01 ± 0.13 **Stress** (Perceived Stress Scale[58] [PSS, 14-item, score 0–40]): **-IG(GI):** BL 29.8 ± 6.6, BL-post −2.00 ± 7.13 **-IG(DS):** BL 29.6 ± 8.9, BL-post 0.07 ± 7.68 **HOMA-IR:**

(Continues)

TABLE 1 (Continued)

Author (year); Country Program name; Study design; Program setting Risk of bias	Baseline data: Sample size (*n*), %F Inclusion criteria Mean age (y) ± SD; BMIz/BMI/BMI percentile (mean ± SD)	Intervention duration; Period of follow-up from baseline *n* enrolled; Retention (R) post-intervention, (R) follow-up	Description of intervention/comparator Key weight-neutral concepts (K) Personnel (P) delivering the intervention	Outcome measurement (evaluation criteria/instruments used) Study findings Change in outcomes, mean ± SD
				-IG(GI): BL 5.2 ± 2.3, BL-post −0.78 ± 2.1 **-IG(DS):** 4.02 ± 3.36, BL-post −0.86 ± 1.7 **-Cohen's d** (within group, average) = 0.3 **Physical activity** (3-Day Physical Activity Recall [3-DPAR, min/day]): *Sedentary-leisure:* **-IG(GI):** BL 173.8 ± 122.6, BL-post −65.4 ± 124* **-IG(DS):** 132.1 ± 59.3, BL-post 72.9 ± 145.8 **-Cohen's d:** greater reduction in IG(GI), post d = 1.0 *Moderate activity (min/day):* **-IG(GI):** BL 103.8 ± 73.5, BL-post 30.4 ± 102.0** **-IG(DS):** 115.8 ± 101.5, BL-post −60.8 ± 122.6 **-Cohen's d:** greater increase in IG(GI), post d = 0.8 - No significant between-group differences post-intervention in moderate-vigorous and vigorous activity. **Energy intake** (kcal/day) (3-day diet records, Nutrition Data System for Research [NDS-R] software program, version 5.0_35): **-IG(GI):** BL 1892 ± 584; BL-post −277.3 ± 512.4 **-IG(DS):** BL 1715 ± 555; BL-post 142.6 ± 623.9 - IG(GI) trend towards energy reduction, compared with IG(DS)**
Study 3 Shomaker et al.[48] (2017), Shomaker et al.[54] (2019), Dalager et al.[52] (2018) case report; USA Mindfulness-based group intervention based on Learning to BREATHE; RCT; university clinic 77% of JBI	*n* = 33; 100% F White (IG: 70.6%), Hispanic (IG: 23.5%), and Native American or American Indian (IG: 5.9%) females 12 to 17 years, BMI ≥85th percentile, depressive symptoms, at risk of T2DM **IG:** 15.01 ± 1.68 years; BMI 30.48 ± 5.21 kg/m^2 (71% with obesity at BL); BMI % ile 94.94 ± 3.45 **CG:** 14.97 ± 1.75 years; BMI 29.19 ± 6.95 kg/m^2 (38% with obesity at BL); BMI % ile 92.75 ± 4.65	6 weeks; 1 year **IG:** *n* = 17; post R = 76%, FU R = 71% **CG:** *n* = 16; post R = 94%, FU R = 81%	**IG:** Weekly 60-min sessions of psychoeducation, group activities and mindfulness practices (e.g., body scan, mindfulness of thoughts/emotions, loving kindness practice, and mindful, gentle movement/yoga). Weekly themes: body awareness, thoughts, emotions, attention, self-acceptance and mindful awareness in daily living. **CG:** Colorado Blues CBT depression prevention program **K:** mindfulness, meditation **P:** lead: clinical child psychologist, facilitator: counselling psychology graduate student in marriage and family therapy	**Feasibility** (attendance ≥80% of sessions, homework completion): Median attendance IG: 6 of 6 sessions, CG: 5 of 6 sessions. Percentage attending ≥80% sessions IG: 92%, CG: 87%. Homework completion ≥75% in 5 of 6 sessions for both groups. **Acceptability** (questionnaire post-intervention): 92%–100% of participants from both groups rated the programs and their health benefits positively and would recommend to others. **Dispositional mindfulness** (Mindful Attention Awareness Scale[59] [MAAS, 15-item, score 1–6]): **-IG:** BL 3.47 ± 0.93; post 4.29 ± 0.83; FU 4.24 ± 1.11 **-CG:** BL 3.33 ± 0.83; post 3.85 ± 0.88; FU 3.81 ± 0.94 **-Cohen's d:** no between-group difference, post d = 0.41; FU d = 0.06 (6-month)

TABLE 1 (Continued)

Author (year); Country Program name; Study design; Program setting Risk of bias	Baseline data: Sample size (*n*), %F Inclusion criteria Mean age (y) ± SD; BMIz/BMI/BMI percentile (mean ± SD)	Intervention duration; Period of follow-up from baseline *n* enrolled; Retention (R) post-intervention, (R) follow-up	Description of intervention/comparator Key weight-neutral concepts (K) Personnel (P) delivering the intervention	Outcome measurement (evaluation criteria/instruments used) Study findings Change in outcomes, mean ± SD
				BMI (kg/m^2): **-IG:** BL-FU −0.43 **-CG:** BL-FU 0.40 **BMIz** (SD): **-IG:** BL-FU −0.16 [CI −0.30, −0.03] **-CG:** BL-FU −0.10 [CI −0.24, 0.03] **Depressive symptoms** (Center for Epidemiologic Studies Depression Scale[60] [CES-D, 20-item, score 0–60]): **-IG:** BL 26.87 ± 6.01; post 16.31 ± 4.71; FU 12.20 ± 10.39 **-CG:** BL 23.30 ± 6.21; post 17.93 ± 7.79; FU 15.42 ± 9.10 **-Cohen's d:** greater reduction in IG, post d = 0.56; FU d = 0.69 (6-month) **Anxiety** (State Trait Anxiety Inventory for Children-Trait Version [STAI-C, 20-item, score 20–60]): **-IG:** BL 44.00 ± 6.95; post 39.92 ± 6.86; BL-FU −7.75 ± 1.39 **-CG:** BL 42.63 ± 5.33; post 39.80 ± 7.34; BL-FU −6.39 ± 1.33 **Global Perceived Stress** (Perceived Stress Scale[58] [PSS, 14-item, score 14–70]): **-IG:** BL 46.29 ± 5.85; post 41.46 ± 7.56; BL-FU −8.71 ± 1.38 **-CG:** BL 44.63 ± 5.33; post 39.00 ± 7.18; BL-FU −5.84 ± 1.31 **HOMA-IR:** **-IG:** BL 2.80 ± 1.32; post 2.13 ± 1.08; FU 2.24 ± 1.64 **-CG:** BL 2.26 ± 1.34 post 3.21 ± 3.45; FU 2.52 ± 1.87 **-Cohen's d:** greater reduction in IG post d = 0.93, no difference FU d = 0.30 (6-month)

Abbreviations: BL, baseline; BMI %ile, BMI percentile; BMI, body mass index (kg/m^2); BMIz, BMI z-score; CBT, cognitive behavioural therapy; CG, control/comparison group; CHO, carbohydrate; CI, 95% confidence interval; DS, digital storytelling; F, female; FU, follow-up; GI, guided imagery; HOMA-IR, homeostatic model assessment of insulin resistance; IG, intervention group; JBI, Joanna Briggs Institute critical appraisal criteria; mgmt, management; n, number of participants; ns, not significant; PA, physical activity; post, post-intervention; SD, standard deviation; T2DM, type 2 diabetes mellitus.
*$p < 0.05$. **$p < 0.10$.

increase ($p = 0.021$) in the non-treatment group (+0.7 kg/m^2, 6 weeks).[49] These changes were not associated with measures of mindfulness (dispositional mindfulness, number of mindful eating sessions, number of meditation sessions).[49] Studies 2 and 3 found no between-group differences in weight-related outcomes (BMI,[48,55] BMIz,[48,55] waist circumference,[55] body fat percentage[55]) post-intervention[48,55] or at one year[48,54] (Table 1). There were no differences in measures of insulin sensitivity/resistance between groups in Study 2, although both groups demonstrated a 15%–21% reduction in HOMA-IR post-intervention.[55] In Study 3, fasting insulin and HOMA-IR were significantly reduced ($p < 0.05$) post-intervention in the treatment group compared with controls,[48] with the reduction in HOMA-IR persisting to 1 year[54] (Table 1). There was no change in perceived stress post-intervention (Study 2[55]) or at 6 months (Study 3[48]). Measured in a single study each, anxiety,[48] fasting glucose[48] and self-reported dietary intake[55] (energy, macronutrients, total/added sugars, fibre) showed no change. Depressive symptoms reduced ($p < 0.05$) post-intervention in the treatment group compared with controls, persisting to 1 year (Table 1) in Study 3.[48] When adjusted for activity level at baseline, moderate physical activity increased significantly (29%) and sedentary activity decreased significantly (38%) post-intervention in the guided imagery group, compared with digital storytelling in Study 2.[55]

The studies met 54%,[49] 69%[55] and 77%[48] of the criteria outlined in the Joanna Briggs Institute Critical Appraisal tool Checklist for Randomised Controlled Trials (Online Supplementary File: Appendix B). The ratings were affected by the small pilot nature of the studies, with lower scores relating mainly to lack of blinding (including lack of blinding of outcome assessors); unclear reporting on follow-up procedures; incomplete analysis of the impact of attrition on outcomes; and lack of intention-to-treat analysis.

4 | DISCUSSION

This review aimed to explore the feasibility and acceptability of weight-neutral interventions in young people with obesity and to determine their effect on health-related outcomes. We identified three pilot studies of short duration (6 or 12 weeks), each with 33 to 37 adolescents. Although the preliminary findings on feasibility and acceptability appear promising, the conclusions are based on limited data from small studies of modest methodological quality. In line with the adult literature, our review revealed few differences in psychosocial or weight-related outcomes between intervention and comparator groups. Further research is needed to establish the safety and efficacy of these interventions, and support their use in clinical practice.

There are some important limitations pertaining to the current literature. As an emerging area of clinical practice, no studies of weight-neutral interventions have been conducted in young adults aged 18 to 24 years. We also identified no studies comparing a weight-neutral approach with conventional weight management in youth with obesity. Notably, current evidence is based on pilot studies lacking statistical power to examine intervention efficacy, and aspects of intervention safety or long term outcomes (>1 year) have not been reported.[66] The findings are limited in their reporting of cardiometabolic outcomes and the use of non-treatment control groups, and may also not be generalisable beyond the current, predominantly female and/or Hispanic/Latino study populations.[66]

Some caution is needed in inferring feasibility from the current evidence. Two studies[48,55] evaluated feasibility based on homework completion and/or attendance and only one study[49] considered retention. The latter school-based study retained 57% of the treatment group participants at 6 weeks, thus reaching the 55% threshold determined a priori for feasibility (Table 1).[49] The 2017 Cochrane Database systematic review of conventional weight management interventions in adolescents indicated that the retention in treatment groups ranged from 78% to 91% (seven studies, of which five were in health care settings and two in the community) in interventions of similar duration (6 weeks to 3 months).[67] Conventional interventions based in schools have reported similar retention (78%,[68] 100%[69]; duration 16 weeks). In adult weight-neutral studies, including those with longer durations, the treatment group retention has ranged from 61%[22] to 92%.[10,70] In these studies, the retention has been lower in the control conditions of non-treatment (33% over 10 weeks),[22] conventional weight management (59% over 6 months),[10] or waitlist (79% over 4 months).[70] In the current review, the opposite was found, with treatment groups having lower retention (57%[49] and 76%[48]; Table 1) compared with comparator groups that did not receive the weight-neutral treatment (65%[49] and 94%[48]). Program retention should be considered when evaluating feasibility, and future research is needed to explore and incorporate adolescent and family views and preferences about weight-neutral interventions.

The results concerning intervention acceptability should also be interpreted with caution. None of the studies specified whether the evaluation of acceptability was undertaken by independent assessors, and it is therefore possible that bias was introduced. Our search identified another weight-neutral intervention ($n = 71$) designed for adolescents with

overweight and obesity,[71] however, was excluded from this review due to the inclusion of healthy weight participants. This study deployed independent focus group facilitators and reported high participant satisfaction with the program. While group formats can generate valuable insights, data collection via group interviews[49] and focus groups[55] lack anonymity and confidentiality. Future studies should deploy independent assessors to evaluate intervention acceptability.

While our review only included three weight-neutral interventions in young people with overweight or obesity, other studies offer additional insights into the potential benefits of the strategies used in these approaches. The search in the current study identified several studies that incorporated adjunctive strategies frequently used in weight-neutral approaches, alongside conventional weight management interventions in young people with obesity.[72–75] Such intervention components included mindfulness,[72,73,75] mindful eating,[73] and eating a variety of nutritious foods, without a focus on energy density or portion control.[74] These studies reported improvements in weight-related,[74] behavioural,[73] psychosocial[72] and cardiometabolic[74] outcomes compared with baseline,[73] waitlist[74] and controls not participating in mindfulness.[72] Mixed approaches may be particularly apt to address health focused preferences of a young person,[41] while also addressing obesity-related complications. It has also been proposed that their focus on psychosocial health may make weight-neutral approaches suitable for certain clinical populations such as individuals with comorbid obesity and eating disorders,[76] anxiety[72] or depression.[4] Further research is warranted in this area.

The strengths of the current review are a comprehensive systematic search across several databases including a broad range of interventions and outcomes in a population not previously reviewed. Inclusion in this review was not limited by sample size, intervention length nor specific outcomes, in order to capture comprehensive data in an emerging area of practice. There are also some limitations. The search was confined to published literature in the English language, possibly over-representing studies with significant findings. The heterogeneity in intervention characteristics, outcome variables and measuring tools constrained direct comparisons between studies, making a meta-analysis and comparisons with adult interventions inappropriate. Despite limited findings, based on three studies, our review provides a valuable summary of the current literature and directions for future research.

Preliminary data suggest weight-neutral interventions may be feasible and acceptable in adolescents with overweight or obesity in the short term. The current evidence base is limited and hence insufficient to guide clinical practice. The diversity of outcomes also limits direct comparisons with conventional weight management. Large-scale, methodologically robust RCTs using weight-neutral strategies for health improvement in young people with overweight and obesity are warranted. These studies should evaluate the short- and long- term physiological, cardiometabolic, psychosocial and behavioural outcomes, along with intervention safety and the comparative effectiveness with conventional weight management approaches.

ACKNOWLEDGMENT

Open access publishing facilitated by The University of Sydney, as part of the Wiley - The University of Sydney agreement via the Council of Australian University Librarians.

CONFLICT OF INTEREST

The authors have no conflict of interest.

AUTHOR CONTRIBUTIONS

JKH, SPG, LAB and HJ conceptualised the review and developed the protocol. JKH developed the search strategy and conducted the database searches. JKH and HJ conducted the screening and critical appraisal. JKH performed the data extraction and HJ checked the accuracy of data extraction. JKH synthesised the data and drafted the manuscript and summary table. NBL, SPG, LAB and HJ critically reviewed the manuscript. All authors have read and approved the manuscript submitted for publication. The authors thank Ms Eve House and Ms Kim Alman for their assistance with screening, data extraction and critical appraisal, and Ms Kanchana Ekanayake for her assistance with developing the database search strategy.

DATA AVAILABILITY STATEMENT

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Hoare JK, Lister NB, Garnett SP, Baur LA, Jebeile H. Weight-neutral interventions in young people with high body mass index: A systematic review. *Nutrition & Dietetics*. 2023;80(1):8-20. doi:10.1111/1747-0080.12729

Received: 28 February 2022 | Revised: 13 September 2022 | Accepted: 16 September 2022

DOI: 10.1111/1747-0080.12781

Nutrition & Dietetics Journal of Dietitians Australia WILEY

REVIEW

The effects of dietary patterns and food groups on symptomatic osteoarthritis: A systematic review

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Funding information
Open access publishing facilitated by The University of Sydney, as part of the Wiley - The University of Sydney agreement via the Council of Australian University Librarians.

Abstract

Aim: To systematically review current literature to determine the association between symptomatic osteoarthritis and dietary patterns, diet quality and food groups in adults aged ≥45 years.

Methods: The review was registered on PROSPERO (CRD42021270891). Cochrane Central Library, Cumulative Index of Nursing and Allied Health Literature, Embase, Medline and Web of Science databases were searched. A total of 3816 records were identified. Eligible articles involved populations aged ≥45 years with symptomatic osteoarthritis, assessing dietary patterns, diet quality or food groups, with pain in joints as outcomes. The Joanna Briggs Institute Critical Appraisal Checklists were used for quality assessment. Grading of Recommendations, Assessment, Development and Evaluation was used to assess the certainty of evidence.

Results: Six cohort studies were included. The Prudent dietary pattern and the Mediterranean dietary pattern reduced the progression of osteoarthritis symptoms. The Western dietary pattern increased symptomatic osteoarthritis progression. Increased total fibre consumption reduced symptomatic osteoarthritis progression and pain worsening, but the effects of fibre from each food group were inconclusive. Diet with high inflammatory potential increased risk of new onset symptomatic osteoarthritis, but the effects of overall diet quality were inconclusive.

Conclusions: The Prudent dietary pattern showed the highest protection on symptomatic osteoarthritis in adults aged 45 years and over. The body of evidence is limited, suggesting that further research is needed to corroborate the estimated effect at a high certainty of evidence, and to incorporate previously unstudied dietary patterns and food groups. Identifying the most beneficial dietary pattern may inform future guidelines for reducing symptomatic osteoarthritis in middle aged and older adults.

Jiayu Zeng and Daniella Kate Franklin are joint first authors.

KEYWORDS
diet quality, dietary pattern, healthy diet, middle aged, osteoarthritis

1 | INTRODUCTION

Osteoarthritis is a chronic and progressive degenerative joint disease, leading to a gradual health and physical function decline.[1] It is the most common form of arthritis leading to knee and hip replacements in Australia, estimated at 9.3% of the total population.[2] The aetiology is categorised by bone joint cartilage deterioration, subchondral bone remodelling, synovial inflammation and articular cartilage loss.[3] There are radiographic and clinical definitions of osteoarthritis. Definitions of radiographic osteoarthritis differ among studies. For example, radiographic osteoarthritis can be defined as a Kellgren–Lawrence grade of 4 at baseline,[4] whilst another study[5] defines radiographic osteoarthritis as a Kellgren–Lawrence grade of ≥2 at follow up. The inflammatory response and the reduction of smooth movements caused by the physiological changes leads to clinical symptoms of pain, aching or stiffness.[6,7] However, not all individuals with joint symptoms are diagnosed with radiographic osteoarthritis.[8] The presence of such clinical symptoms plus the radiographic osteoarthritis is named as symptomatic osteoarthritis.[8] The activities of daily living and the quality of life are largely impacted in individuals with osteoarthritis.[9] Therefore, osteoarthritis is considered one of the leading causes of disability among the older population.[10]

The prevalence of osteoarthritis is strongly related to age and gender, increasing significantly from 45–54 years to 55–64 years (9.7%–20.7%) according to the Australian National Health Survey 2017–2018.[2] It affects approximately 6% of Australian males (n = 805 800, estimated) and 10% of Australian females (n = 749 200, estimated).[2] Osteoarthritis accounted for 19% of the total burden of disease due to musculoskeletal conditions in Australia in 2015.[11] Osteoarthritis' burden is projected to increase exponentially due to Australia's ageing and obese population, with prevalence expected to reach 3 million Australians by 2032[1] and 130 million internationally by 2050.[12]

There are multiple risk factors involved in the generation and progression of osteoarthritis. Unmodifiable risk factors include age, gender, ethnicity, genetics, joint malalignment, and family history.[6,8,9] Congenital or acquired joint shape and malalignment are associated with greater osteoarthritis risk in younger individuals.[13,14] Modifiable risk factors include diet, overweight and obesity, injury, occupational overuse of joints, physical activity, bone density, joint laxity, and muscular weakness.[6,8,9] The management of osteoarthritis involves education, physical therapy, diet and exercise interventions, weight loss and surgery.[6] The use of medications reduces pain, such as paracetamol, or reduces swelling and pain, such as the use of non-steroidal anti-inflammatory drugs, including diclofenac sodium, celecoxib, meloxicam and naproxen.[6]

As both a risk factor and a management strategy, the association between diet and osteoarthritis has been a focused topic. Low intake of certain nutrients, for instance Vitamin D, Vitamin C, Vitamin E, Vitamin K and magnesium, have been found to be associated with increasing the risk of osteoarthritis progression or worsening of symptoms.[15–19] In contrast, randomised controlled trials of supplementing single nutrients Vitamin D, E and K have not shown any protective effects for osteoarthritis.[20–22] This suggests that focusing on individual nutrients may be insufficient, and the effects of food groups and overall dietary patterns should be the focus when studying diet-disease relationships.[23,24]

Other than diet, overweight and obesity is another osteoarthritis risk factor. It increases weight-bearing joint and cartilage load and contributes to degradation.[25,26] Approximately 70% of osteoarthritis is preventable by avoiding excess weight gain and joint injuries.[1] Foods have synergistic health and disease effects,[27] influencing clinical nutritional recommendations on osteoarthritis.[28,29] There are limited primary studies, such as randomised controlled trials and cohort studies, and no systematic reviews that have shown that the relative risk of osteoarthritis and presence of symptomatic osteoarthritis is negatively associated with anti-inflammatory diets (e.g., DASH, Prudent and Mediterranean diet),[24,30–33] and positively associated with pro-inflammatory diets (e.g., Western diet).[4,32,34] However, associations between diet and osteoarthritis-specific symptoms after follow-up remains inconclusive, and no systematic analysis has been conducted to date to assess the quality of the evidence. As prevalence increases in individuals 45+ years with greater progression with age, this review aims to scope associations of dietary patterns, diet quality, and food groups with symptomatic osteoarthritis in adults aged 45 years and older with joint pain, aching or stiffness, with radiographic osteoarthritis. This systematic

review will synthesise available evidence in the literature on associations of the consumption of pro- and anti-inflammatory diets and presence of symptomatic osteoarthritis, using outcome measurements such as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) pain scale. This will subsequently add to the body of evidence in the literature.

2 | METHOD

This systematic review was registered at the PROSPERO International Prospective Register of Systematic Reviews prior to the study commencement (Registration number: CRD42021270891). The review was reported by following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (see full PRISMA checklist in Table S1).

A comprehensive literature search was conducted on 2nd September, 2021 using electronic databases Cochrane CENTRAL Library (via Ovid), Cumulative Index of Nursing and Allied Health Literature (CINAHL), Embase (via Ovid), MEDLINE (via Ovid) and Web of Science (Core Collection). Reference lists of final included articles were searched by 4th October, 2021 subsequent to database search. Three groups of key terms indicating the population, exposure and outcome of interest were adapted from an original search strategy to each of the databases. The original search strategy was formed as follows (with full search strategies in Table S2).

For extensive and thorough research on dietary patterns and symptomatic osteoarthritis, the search strategy included the terms 'diet', OR 'diet therapy', OR 'diet pattern', OR 'diet intake', OR 'diet treatment', OR 'diet restrict', OR 'diet therapy', OR 'meal pattern', OR 'eating pattern', OR 'food pattern' OR 'eating pattern' OR 'food pattern' OR 'diet habit' OR 'food' OR 'food group' AND 'Symptomatic Diseases' OR 'symptomatic' AND 'osteoarthritis' OR 'Cartilage' OR 'chondral' OR 'meniscal' OR 'meniscus' OR 'bone marrow' OR 'subchondral' OR 'osteophyte' OR 'effusion' OR 'synovitis' OR 'ligament' OR 'attrition' OR 'fat pad' AND 'Joint' AND 'pain', OR 'aching' OR 'stiffness', OR 'tightness' AND 'middle aged', OR '45+ years', OR 'older' OR 'ageing', OR 'aged', OR 'elder', OR 'elderly'.

The first and second screenings were conducted in duplicate by two reviewers. The first screening included assessing the titles and abstracts of each study, and the second screening included a full-text review. Both screenings were against the inclusion and exclusion criteria listed in Table 1. Eligible articles involved populations aged ≥45 years with symptomatic osteoarthritis, assessing dietary patterns, diet quality, or food groups, with pain, stiffness in joints and physical function as outcomes. Eligible study designs were randomised controlled trials and cohort studies. Consensus was reached after comparing and discussing the results of screening by the two reviewers, and another two reviewers were available if consensus could not be reached by two reviewers.

Data were extracted in duplicate from each study by two reviewers and the extracted data were checked by two reviewers. Data extracted included study details (author, year of publication, study's country, study design, setting, recruitment, eligibility criteria, follow-up duration), population characteristics (age, sex, race, sample size, withdrawal or exclusions, underlying disease status of participants), intervention or exposure (dietary pattern studied, diet assessment method, level of dietary control, randomisation and comparator) and outcomes, statistical method and potential confounders. Authors were contacted for any missing full text or data.

The quality assessment of included studies was conducted in duplicate by two reviewers. The Joanna Briggs Institute Critical Appraisal Checklist was used for risk of bias assessment at the cohort study level.[36] The Joanna Briggs Institute appraisal tool consists of 11 questions with 4 answer options: 'yes', 'no', 'unclear' and 'not applicable' (Table 4). The final judgement of including or excluding certain studies was determined by the overall appraisal. Studies which answered more than three 'no' or 'unclear' were considered poor quality and therefore were excluded. Any disagreement was discussed by two reviewers, and two additional reviewers involved if consensus was not reached.

The certainty of the body of evidence for each outcome as effect estimates by dietary pattern was assessed using GRADE (Grading of Recommendations Assessment, Development and Evaluation) and was categorised as 'high', 'moderate', 'low' and 'very low'. The certainty of evidence could be downgraded either one or two levels based on five factors: risk of bias, inconsistency, imprecision, indirectness and publication bias. 'Serious' indicates one level downgrading and 'very serious' indicates two levels downgrading. GRADE guideline 6 suggests population sample sizes over 400 are likely to meet optimal information size.[40] The downgrading of imprecision was determined by if the study had a small sample size <400, and/or wide 95% confidence intervals (CIs). Studies were downgraded by one level if CIs included both null effect and appreciable benefit (CI < 0.75) or harm (CI > 1.25). Studies were downgraded by two levels if CIs included both appreciable benefit and harm. Consensus of the GRADE results was reached between the two reviewers, and a third reviewer was available if consensus could not be reached by two reviewers.

TABLE 1 PICOS inclusion/exclusion criteria

Parameter	Inclusion criteria	Exclusion criteria
Population	1. Individuals aged 45 years and older with pain, aching or stiffness in a joint with radiographic osteoarthritis.[2]	1. Individuals aged <45 years with major illnesses. 2. Individuals who underwent surgical treatment for osteoarthritis and individuals with neurological or cardiovascular diseases. 3. Individuals in hospitals or institutions.
Intervention or Exposure	1. Interventions of dietary patterns, diet quality or food groups including all modes of deliveries such as direct meal deliveries and dietary advice provided by trained professionals. 2. Interventions involving dietary patterns, diet quality or food groups with the manipulation of nutrient composition with a whole diet approach or dietary patterns supplemented with food items. 3. Exposures to dietary patterns, diet quality or food groups assessed by one or more of the following methods: dietary history taken by a trained professional, food frequency questionnaire, 24-h recall or weighed food record.	1. Dietary patterns supplemented with supplements 2. Studies including other interventions in addition to dietary patterns. 3. Non-food exposures involving single nutrients or supplements. 4. Exposures to dietary patterns assessed indirectly through grocery item lists.
Comparison	1. Inactive control diet (such as a placebo, no treatment, usual care without dietary advice, or a waiting list control). 2. Comparator diet. 3. Non-exposure to the diet.	Not applicable.
Outcomes	1. The primary outcomes included pain, stiffness in a joint and physical function.	1. Studies that did not assess symptoms that are specific to osteoarthritis. For example, knee structure changes, radiographic osteoarthritis progression, quality of life, and so on.
Study design	1. Randomised controlled trials, cluster randomised controlled trials, pseudo-randomised controlled trial, non-randomised controlled clinical trials, cluster trials, prospective cohort studies, retrospective cohort studies.	1. Controlled before-after studies, interrupted time studies without a control group, cross-sectional studies, case series, case reports, non-study based sources, narrative reviews and systematic reviews. 2. Interrupted time-series studies with a control group, case–control studies, cross-sectional studies and nested case–control studies.
Language	English	Other than English

3 | RESULTS

There were 3816 records identified from the database on 2nd September 2021. After removing 804 duplicates, 3012 papers were screened by title and abstract against the inclusion and exclusion criteria. From these, 48 articles were retrieved in full-text to assess eligibility. After failed attempts to contact the authors, 12 papers failed to be assessed for full-text screening. Besides these, reasons for exclusion included dietary intervention for weight loss involving fasting or energy restriction ($n = 12$), ineligible population ($n = 6$), dietary intervention involving supplements ($n = 5$), non-dietary variables ($n = 7$), exposure involving diet and other treatments spontaneously ($n = 2$), and ineligible study design ($n = 2$). Three articles were included in the review,[4,37,39] and further records were identified from reference lists of eligible articles ($n = 5$) by 4th October 2021. Of these, two articles were removed due to ineligible study design.[30,41] A total of six articles were included for data extraction and quality

assessment. The detail of study selection is presented in the PRISMA flow diagram (Figure 1).

The characteristics of included articles are presented in Table 2. Studies involved participants with both males and females, aged 45 years and over and with a history of osteoarthritis symptoms ($n = 6$). All six articles were prospective cohort studies from the United States ($n = 4$),[4,34,37,38] Australia ($n = 1$),[39] and the United Kingdom ($n = 1$).[5] Of these, four articles collected data from the same cohort study, the Osteoarthritis Initiative,[4,34,37,38] one article used the data from the Vitamin D Effect on Osteoarthritis (VIDEO) study[39] and one article compared the data from Osteoarthritis Initiative and the Framingham study.[5]

All six studies included adequate follow-up periods, ranging from 2 to 9.5 years, and sufficient sample size, ranging from 392 to 4470 participants ($n = 6$). One study had greater than 30% loss to follow-up, over a 72 month period.[4] However, statistical analysis was applied for adjusting follow-up time points, which was considered acceptable (Table 4). One study had greater than 30% exclusion rate due to ineligible data (participants with prior total knee replacement at baseline ($n = 64$), participants with missing dietary data ($n = 129$), participants with extreme energy intake ($n = 111$), participants with missing symptomatic osteoarthritis data at baseline ($n = 168$), participants with prevalent symptomatic osteoarthritis at baseline ($n = 1246$), and participants with missing incident symptomatic osteoarthritis data at 48 month follow-up ($n = 138$)).[34] Participants with major diseases were excluded from all six articles, and participants with severe osteoarthritis were excluded from two articles.[4,39] In addition, all studies utilised validated methods to measure exposure and outcome. Dietary exposures included Western pattern and Prudent pattern measured by 70-item Block Brief food frequency questionnaire[4]; Mediterranean diet,[38] inflammatory potential of diet,[34] and dietary fibre intake[5,37] measured by Block Brief 2000 FFQ; and overall diet quality measured by Dietary Questionnaire for Epidemiological Studies v2[39] and 70-item Block Brief food frequency questionnaire.[4] The majority of studies only measured exposure once at baseline except the Framingham study, which measured dietary intake at baseline and 4 years later.[5] In terms of outcomes, two studies had osteoarthritis symptom progression,[4,39] two studies had incident symptomatic osteoarthritis,[5,34] one study had pain progression[37] and one study had both incident symptomatic osteoarthritis and pain progression.[38] All studies measured outcome several times at each follow-up time point (Table 2 column 1).

The quality of evidence for each outcome was presented in Table 3. All six articles had less than three

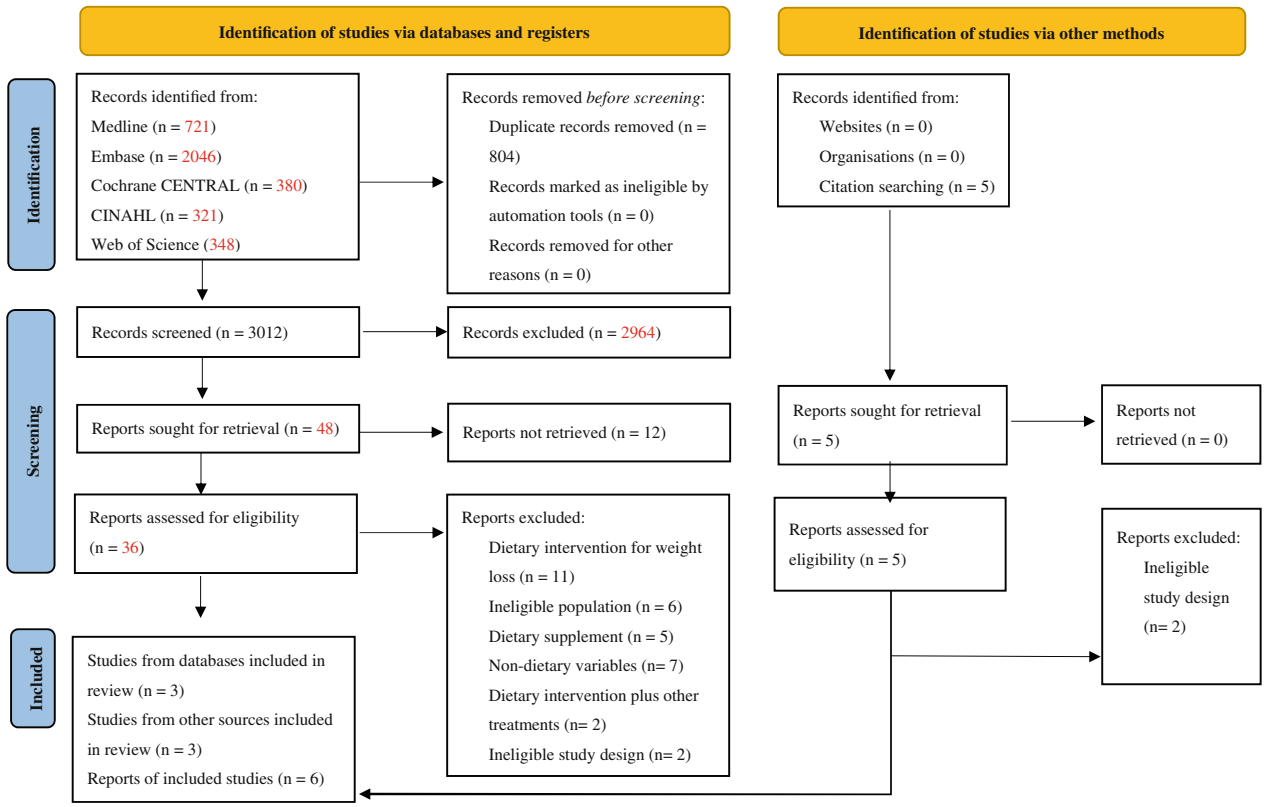

FIGURE 1 Flow diagram of the literature search. CENTRAL, Cochrane Central Register of Controlled Trials; CINAHL, Cumulative Index of Nursing and Allied Health Literature.

TABLE 2 Characteristics of included studies

Study details	Sample size and characteristics	Recruitment and intervention time	Inclusion/exclusion criteria	Outcome measure	Dietary intake measurements
American OAI Cohort					
Dai et al.[37] the United States, prospective cohort, 96 months	*Final sample*: 4470/4796 (93.2% participation) *Withdrew/Excluded*: 326 3703 knees with OA (Ages 45–79 years) 41.5% men	American OAI Launched by the NIH, from February, 2004 to May 2006	*Inclusion*: Participants Aged 45 and over, overweight, previous knee injury or surgery, knee pain during the past year. Family history of knee replacement. *Exclusion*: Rheumatoid arthritis, joint replacements in both knees, unable to walk without assistance, unable to undergo MRI of the knee, history of TKR or PKR at baseline.	*Methods/Measures*: Examiners studied knee pain development patterns over 96 months using the WOMAC pain subscale of five activity items: walking, stair climbing, nocturnal, rest and weight bearing.	*Methods/Measures*: Validated Block Brief 2000 FFQ at baseline, calculated based on the food composition database for nutrients in the SNHNES and separated into quartiles of fibre intake: (I) Total energy (kcal/day), median IQR, (II) total dietary fibre (g/day), median IQR, (III) grain fibre (g/day), median IQR, (IV) fruit and vegetable fibre (g/day), median IQR and (V) nut and legume fibre (g/day) median IQR).
Veronese et al.[38] the United States, prospective cohort, 48 months	*Final sample*: 4330/4796 (90.2% participation). *Withdrew/excluded*: 466 (63 = TKR, 118 = insufficient information and 285 = no data regarding outcomes of interest). (Ages 45–79 years) 58.0% females and 42% males at baseline. Mean age: 61.1 years	American OAI recruited participants across four American states between February 2004 and May 2006.	*Inclusion*: Participants aged between 45 and 79 years of age from OAI, validated exposure (Mediterranean Diet adherence) and outcomes (pain worsening, SxOA and/or ROA). *Exclusion*: Participants had total knee replacement at baseline.	*Methods/Measures*: Question regarding knee pain: 'During the past 30 days, have you had pain, aching or stiffness in your right/left knee on most days?' Knee pain: WOMAC (Western Ontario and McMaster Universities Osteo-arthritis Index) pain subscale.	*Methods*: Block Brief 2000 food frequency (FFQ). *Measures*: Adherence to a Mediterranean diet presented by aMED.
Liu et al.[34] the United States, longitudinal prospective cohort study, 48 months	*Final sample*: 2940/4796 *Withdrew/excluded*: 1856/4796 (61.3% participation). (Ages 47–79 years) 58.5% female; mean BMI at baseline 28.0 kg/m^2.	The American OAI recruited participants from four US states over a 48 month follow up.	*Inclusion*: Participants were aged between 47 and 79 years of age from OAI, with realistic energy intake, with incident SxOA or ROA.	*Methods/Measures*: SxOA: pain, aching or stiffness on more than 15 days of a month during the past year.	*Methods*: Block Brief 2000 Food Frequency Questionnaire *Measures*: Habitual dietary intake of nutrients and foods at baseline to

TABLE 2 (Continued)

Study details	Sample size and characteristics	Recruitment and intervention time	Inclusion/exclusion criteria	Outcome measure	Dietary intake measurements
			Exclusion: Participants with total knee replacement at baseline, with missing dietary data, with extreme calories intake, with missing SxOA or ROA data at baseline, with prevalent SxOA or ROA at baseline, with missing incident SxOA or ROA data at 48-month follow-up.		estimate dietary inflammatory potential presented by quartiles of DII score per 1000 kcal energy
Xu et al.[4] the United States, prospective cohort, 72 months.	*Final sample*: 2757/4134 (66.7% participation) *Number of loss of follow-up*: 129 in year 2, 139 in year 3, 221 in year 4 and 1377 in year 6 (due to death, TKR or nonresponse) (Ages 45–79 years) 40.5% male; Mean age: 62.1 ± 9.0; 78.8% white, 18.2% African American, 3.1% others; 16.7% high school education or lower, 46.1% college education, 37.1% higher than college education; 13.2% ≤ $25 K family income, 25.6% $25–50 K family income, 34.6% $50–100 K family income, 20.5% > $100 K family income, 8.9% depressed; 53.4% non-smoker, 6.2% smoker, 40.4% ex-smoker; 18.2% BMI <25, 39.9% BMI 25–30, 41.9% BMI ≥30	American OAI launched by the NIH, from February, 2004 to May 2006	*Inclusion*: Participants aged 45 and over from OAI with mild to moderate KOA in at least 1 knee (KL grade of 1, 2 or 3) at baseline based on x-ray reading. *Exclusion*: Participants without OA, with severe ROA (KL grade of 4 at baseline), with lateral joint space narrowing, with unrealistic total daily calorie intake (<800 or >4200 kcal for men, <500 or >3500 kcal for women).	*Measures/Methods*: SxOA: Validated WOMAC pain, functional disability and total scores.	*Methods*: Validated 70-item Block Brief FFQ at baseline. *Measures*: Average frequency of consumption for each food item aggregated into 25 food groups. Diet quality which is represented by the scores of Western and Prudent diet separately and a combined score derived by factor-loading matrix using Block Brief FFQ.
American OAI and Framingham Offspring Cohorts					
Dai et al.[5] the United States, the United Kingdom,	*Final sample*: OAI: 4256/4796	The American OAI recruited participants from 2004 to 2006 in the	*Inclusion*: Participants who were recruited were aged between 45 and 79 years of age, from OAI	*OAI/Framingham Study Methods/Measures*:	*OAI* *Methods*: Block Brief 2000 food frequency (FFQ)

(Continues)

TABLE 2 (Continued)

Study details	Sample size and characteristics	Recruitment and intervention time	Inclusion/exclusion criteria	Outcome measure	Dietary intake measurements
prospective cohort, 2 years for OAI and 9.5 years for the Framingham study.	Framingham Study: 1137/1268 *Withdrew/excluded*: OAI: 540 (89% participation). Framingham Study: 131 (88.1%) participation. (Ages 45–79 years) OAI: 41.7% men; mean age 61.4 years; BMI 28.6%. Framingham Study: 45.5% men; mean age 53.9 years; BMI 27	United States. Participants were also recruited from the Framingham Offspring cohort assembled in 1971.	with incident ROA, SxOA, or pain worsening, or from the Framingham study, with incident ROA or SxOA and valid fibre and energy intake. *Exclusion*: OAI: loss to follow-up at 48 months, with extreme calories intake, with total knee replacement at baseline, with missing or prevalent SxOA or ROA at baseline, with missing WOMAC pain score at baseline or at 48 months. Framingham: Loss to follow-up at exam 7, with missing data on fibre intake.	SxOA: response to the question 'During the past 30 days, have you had pain, aching, or stiffness in your right/left knee on most days? And ≥14% in WOMAC pain score difference between baseline and each follow-up.	*Measures*: Dietary fibre intake including total dietary fibre, cereal fibre, fruit and vegetable fibre and nut and legume fibre. *Framingham Study*: *Methods*: Harvard validated *Measures*: Habitual dietary intake and dietary fibre intake
VIDEO Study					
Ruan et al.[39] Australia, prospective cohort, 24 months	*Final sample*: 392/413 (94.9% participation) *Withdrew/Excluded*: 21 Mean age: 63.26 years (Ages 50–79 years) 50.51% male Mean height: 168.36 cm Mean weight: 83.87 kg Mean BMI: 29.56 kg/m^2	The VIDEO study, conducted between June 2010 and December 2013. Recruitment began from June 2010 to December 2011 in Tasmania and Victoria, Australia	*Inclusion*: Aged between 50 and 79 years, had clinical knee OA compiled with the ACR criteria, pain score >20 mm on visual analog scale, had an ACR function class rating of I, II and III, good health scored 0–2 on a 5 point Likert scale (from 0 indicating very good health to 4 indicating very poor health). *Exclusion*: Grade 3 knee ROA, contraindication to magnetic resonance imaging (MRI), rheumatic diseases and other severe diseases.	*Methods/Measures*: Assessment of OA symptoms at baseline, 3, 6, 12 and 24 months using WOMAC OA Index.	*Methods/Measures*: (i) Dietary intake was assessed at baseline using the DQES v2. Participants reported usual consumption over the past 12 months of 74 foods on a 10-point frequency scale. (ii) Diet quality was assessed using the ARFS calculated based on DQES v2 items.

Abbreviations: aMED, Mediterranean Diet Score; ACR, American College of Rheumatology; AQoL-4D, four-dimensional assessment of quality of life; ARFS, Australian Recommended Food Score; BMI, Body Mass Index; BMLs, bone marrow lesions; DII, Dietary Inflammatory Index; DQES v2, Dietary Questionnaire for Epidemiological Studies version 2; FFQ, Food Frequency Questionnaire; g/day, grams per day; IQR, interquartile range; kcal/day, kilocalories per day; JSW, joint space width; K, $1000; KL, Kellgren–Lawrence; KOA, knee osteoarthritis; MRI, magnetic resonance imaging; NIH, National Institutes of Health; OA, osteoarthritis; OAI, American Osteoarthritis Initiative; PHQ-9, 9-Items Patient Health Questionnaire; PKR, partial knee replacement; QoL, quality of life; ROA, radiographic osteoarthritis; SNHNES, Second National Health and Nutrition Examination Survey; SxOA, symptomatic osteoarthritis; TKR, total knee replacement; VIDEO, Vitamin D Effect on Osteoarthritis; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

questions which answered 'no' or 'unclear' using Joanna Briggs Institute Critical Appraisal Checklists (Table 4). More details of individual articles are discussed below.

The results of the review were heterogeneous, and no studies explored the association of the same dietary pattern with the same outcome. The outcomes grouped by dietary pattern and certainty of evidence are presented in Table 3.

Two studies evaluated overall diet quality effects on symptomatic osteoarthritis.[4,39] WOMAC and Visual Analog Scale scores were evaluated using Australian Recommended Food Score associations in the Vitamin D Effect on Osteoarthritis (VIDEO) study conducted on male and female participants between 2010 and 2013 with a 24-month follow up. After adjusting for confounders, Australian Recommended Food Score was not significantly associated with WOMAC knee pain, joint stiffness, physical dysfunction and knee pain Visual Analog Scale over 24 months.[39]

The effects of diet quality on symptomatic osteoarthritis were evaluated via the American Osteoarthritis Initiative from February 2004 to May 2006 in male and female participants aged 45–79 years, using a validated 70-item Block Brief Food Frequency Questionnaire measuring diet quality.[4] A significant negative effect of increasing poor diet quality was observed on symptomatic knee osteoarthritis progression at 24-months follow up after adjusting for confounders (p-trend <0.01).

The effects of dietary inflammatory potential on symptomatic knee osteoarthritis were evaluated using a validated Block brief 2000 food frequency questionnaire using the American Osteoarthritis Initiative cohort, with a 48-month follow up.[34] Participants were stratified by quartiles of Energy-density Dietary Inflammatory Index score; OR (95%). A linear statistically-significant relationship was observed between a higher pro-inflammatory diet and symptomatic knee osteoarthritis (OR 1.43 [1.16, 1.76] $p = 0.001$).

The effects of Western dietary patterns and Prudent dietary patterns on symptomatic osteoarthritis progression were evaluated using American Osteoarthritis Initiative data.[4] Symptomatic osteoarthritis progression significantly increased with higher compliance of Western patterns represented by higher quartiles, with greater intakes of red and/or processed meats, refined grains and potato chips (p-trend <0.01). Symptomatic osteoarthritis progression significantly reduced with increased adherence to Prudent dietary patterns of high vegetable, fruit, fish, wholegrain and legume intake, represented by higher quartiles of intake compared to lower intakes (p-trend <0.01).

The effects of the Mediterranean Diet on symptomatic osteoarthritis and pain worsening was evaluated using the American Osteoarthritis Initiative cohort using the Block Brief 2000 food frequency questionnaire to calculate Mediterranean Diet scores over a 48-month follow up.[38] Participants in quintile 5 with greater adherence to the Mediterranean Diet reported a significantly lower pain worsening and symptomatic osteoarthritis progression risk, and an increase in one standard deviation of the Mediterranean Diet score reduced the pain worsening and symptomatic osteoarthritis risk. However, the trend was inconclusive.

The effects of dietary fibre on WOMAC pain were evaluated using the Block Brief 2000 food frequency questionnaire using the American Osteoarthritis Initiative cohort with a 96-month follow up.[37] Statistically-significant effects were observed between higher total fibre and fruit and vegetable fibre intake and moderate knee pain and between higher total, cereal and fruit and vegetable fibre intake and severe knee pain.

Associations between dietary fibre and incident symptomatic osteoarthritis and pain worsening were evaluated using the American Osteoarthritis Initiative cohort between 2004 and 2006 and Framingham Offspring Cohort with a 9.5 year follow up.[5] In the American Osteoarthritis Initiative, pain worsening was inversely associated with total fibre intake ($p = 0.03$). However, no significant effects were observed between each fibre subtype and pain worsening in the American Osteoarthritis Initiative. In the Framingham Study, total fibre intake was inversely associated with symptomatic osteoarthritis incidence. Moderate fruit and vegetable fibre intake and high nut and legume fibre intake had reduced symptomatic osteoarthritis incidence.

The certainty of the evidence was very low for symptomatic osteoarthritis progression, knee pain visual analog scale, WOMAC joint stiffness, WOMAC knee pain, total WOMAC, WOMAC physical dysfunction and WOMAC pain. The certainty of the evidence was low for pain worsening (Table 5).

The overall risk of bias was very serious across the six studies. The VIDEO[39] and American Osteoarthritis Initiative studies[4,34,37,38] were downgraded due to cohort study design without concealment to data analysis, significantly different baseline participant characteristics across exposure groups or no statistical analysis to evaluate baseline participant characteristic differences, and unclear strategies utilised to address incomplete follow up (Table 3). The study that compared the results of American Osteoarthritis Initiative and Framingham Offspring Cohorts[5] was downgraded due to cohort study design, lack of baseline participant characteristic statistical comparison and unclear strategies to address incomplete follow-up (Table 3).

The imprecision of individual studies varied (Table 3). The associations between diet quality and WOMAC knee pain, joint stiffness and knee pain Visual Analog Scale had wide CIs spanning appreciable benefit and

TABLE 3 Statistical analyses of cohort studies

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
Overall diet quality			
SxOA progression	Xu et al. (2020)[4]	*Dietary patterns and KL progression*: Separate Cox proportional hazards models with discrete likelihood method for follow-up time. *Dietary patterns and JSW/Dietary patterns and symptomatic KOA progression*: Linear mixed models. *Confounders*: age, sex, race, baseline KL grade, assessed depression (defined as the CES-D 20 items scale >16), BMI, weight change from baseline, physical activity, total energy intake, traumatic knee injury, knee surgery, income, education, smoking and alcohol intake and pain relief medication usage.	*Quartiles of the combined diet score, more healthy diet: OR (95% CI), p-value, cases/ person- years* Q1: 1.00, referent, 591/1128 Q2: 1.19 (1.01, 1.41), $p = 0.04$, 617/1176 Q3: 1.22 (1.03, 1.44), $p = 0.02$, 613/1114 Q4: 1.29 (1.08, 1.53), $p < 0.01$, 619/1044 p-trend <0.01 (significant)
Knee pain VAS	Ruan et al. (2021)[39]	Associations of diet quality with OA symptoms, knee symptoms, QoL and OA comorbid conditions estimated using the mixed-effects linear regression model. *Confounders*: Age, sex, BMI, serum vitamin D level, energy intake, visit time, education, work status and work type.	β (95% CI): −0.12 (−0.38, 0.14); $p = 0.36$ (non-significant)
WOMAC joint stiffness			β (95% CI): −0.28 (−0.77, 0.20); $p = 0.25$ (non-significant)
WOMAC knee pain			β (95% CI): −0.55 (−1.52, 0.42); $p = 0.27$ (non-significant)
Total WOMAC			β (95% CI): −4.00 (−8.91, 0.90); $p = 0.11$ (non-significant)
WOMAC physical dysfunction			β (95% CI): −3.14 (−6.75, 0.48); $p = 0.09$ (non-significant)
Dietary Inflammatory Potential			
SxOA	Liu et al. (2020)[34]	Test for linear trend using the median value of each quartile of E-DII score as a continuous variable in the regression model. Alternative analyses were conducted fitting E-DII as a continuous variable in models. *Confounders*: Age, sex, race, educational attainment, annual income, physical activity and tobacco use.	*Quartiles of E-DII score: OR (95% CI), no. of cases* Q1: 1.00 referent, 218/1472 Q2: 1.13 (0.92, 1.40), 237/1470 Q3: 1.27 (1.04, 1.56), 260/1470 Q4: 1.43 (1.16, 1.76), 263/1468 $p = 0.001$ (significant)
Western diet			
SxOA progression	Xu et al. (2020)[4]	*Dietary patterns and KL progression*: Separate Cox proportional hazards models with discrete likelihood method for follow-up time.	*Quartiles of the Western diet score: OR (95% CI), p-value, cases/person- years* Q1: 1.00 referent, 594/1156

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
		Dietary patterns and JSW/Dietary patterns and symptomatic KOA progression: Linear mixed models. *Confounders*: age, sex, race, baseline KL grade, assessed depression (defined as the CES-D 20 items scale >16), BMI, weight change from baseline, physical activity, total energy intake, traumatic knee injury, knee surgery, income, education, smoking and alcohol intake and pain relief medication usage.	Q2: 1.06 (0.89, 1.25), $p = 0.51$, 609/1130 Q3: 1.15 (0.97, 1.37), $p = 0.11$, 608/1105 Q4: 1.26 (1.06, 1.50), $p < 0.01$, 629/1071 p-trend <0.01 (significant)
Prudent diet			
SxOA progression	Xu et al. (2020)[4]	*Dietary patterns and KL progression*: Separate Cox proportional hazards models with discrete likelihood method for follow-up time. *Dietary patterns and JSW/Dietary patterns and symptomatic KOA progression*: Linear mixed models. *Confounders*: age, sex, race, baseline KL grade, assessed depression (defined as the CES-D 20 items scale >16), BMI, weight change from baseline, physical activity, total energy intake, traumatic knee injury, knee surgery, income, education, smoking, and alcohol intake and pain relief medication usage.	*Quartiles of the Prudent diet score: OR (95% CI), p-value, cases/person-years* Q1: 1.00 referent (lowest), 618/1077 Q2: 0.90 (0.76, 1.07), $p = 0.22$, 611/1094 Q3: 0.90 (0.76, 1.06), $p = 0.21$, 614/1141 Q4: 0.71 (0.60, 0.84), $p < 0.01$, 597/1150 p-trend <0.01 (significant)
Mediterranean diet			
Pain worsening	Veronese et al. (2019)[38]	Multivariable Poisson regression analysis p values for trends: Jonckheeree Terpstra test for continuous variables, Mantel–Haenszel Chi-square test for categorical variables. *Confounders*: Race; educational attainment; BMI; yearly income; depressive symptoms measured using CES-D; smoking habits; physical activity level evaluated using PASE; Charlson Comorbidity Index score; daily energy intake; number of medications at baseline.	*Quintiles of aMED score: RR (95% CI), p-value* aMED 24: 1.00 referent aMED 25–27: 0.98 (0.95, 1.02), $p = 0.45$ aMED 28–30: 0.99 (0.95, 1.03), $p = 0.72$ aMED 31–32: 0.99 (0.94, 1.03), $p = 0.53$ aMED >32: 0.96 (0.91, 0.999), $p = 0.047$ Increase in one SD: 0.98 (0.97, 0.998), $p = 0.04$ (significant)
Symptomatic knee OA	Veronese et al. (2019)[38]	Multivariable Poisson regression analysis p values for trends: Jonckheeree Terpstra test for continuous variables, Mantel–Haenszel Chi-square test for categorical variables. *Confounders*: Race; educational attainment; BMI; yearly income; depressive symptoms measured using CES-D;	*Quintiles of aMED score: RR (95% CI), p-value* aMED ≤24: 1.00 referent aMED 25–27: 0.94 (0.85, 1.04), $p = 0.25$ aMED 28–30: 0.91 (0.82, 1.009), $p = 0.07$ aMED 31–32: 0.93 (0.83, 1.05), $p = 0.26$ aMED >32: 0.91 (0.82, 0.998), $p = 0.048$

(Continues)

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
		smoking habits; physical activity level evaluated using PASE; Charlson Comorbidity Index score; daily energy intake; number of medications at baseline.	Increase in one SD: 0.96 (0.93, 0.997), $p = 0.04$ (significant)
Dietary fibre intake			
WOMAC pain (mild)	Dai et al. (2017a)[37]	Group-based trajectory modelling procedure using a multinomial modelling strategy. *Confounders*: demographics, tobacco and alcohol use, depressive symptoms measured by CES-D, knee injury and surgery, medication use, and physical activity assessed by PASE.	*Quartiles of total fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (8.6 [6.3–11.3]): 1.00 referent, 378/3703 Q2 (12.5 [9.9–15.6]): 0.88 (0.66, 1.17), 374/3703 Q3 (15.2 [12.2–19.0]): 0.76 (0.58, 1.01), 346/3703 Q4 (20.6 [16.2–26.5]): 0.87 (0.65, 1.16), 369/3703 p-trend = 0.28 (non-significant) *Quartiles of cereal grain fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (3.7 [2.5–5.2]): 1.00 referent, 366/3703 Q2 (5.0 [3.5–6.8]): 1.28 (0.96, 1.69), 388/3703 Q3 (5.7 [3.9–8.0]): 1.00 (0.76, 1.31), 376/3703 Q4 (6.8 [4.5–9.8]): 1.01 (0.77, 1.33), 335/3703 p-trend = 0.6 (non-significant) *Quartiles of fruit and vegetable fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (3.8 [2.6–5.4]): 1.00 referent, 367/3703 Q2 (6.1 [4.5–8.1]): 1.13 (0.84, 1.51), 369/3703 Q3 (7.8 [6.0–10.0]): 1.17 (0.88, 1.56), 384/3703 Q4 (10.5 [7.8–14.0]): 0.90 (0.68, 1.20), 345/3703 p-trend = 0.35 (non-significant) *Quartiles of legume and nut fibre (median [IQR] g/day):OR (95% CI), no. of cases* Q1 (0.8 [0.4–1.4]): 1.00 referent, 380/3703 Q2 (1.4 [0.8–2.1]): 1.03 (0.78, 1.36), 382/3703 Q3 (1.6 [1.0–2.6]): 0.88 (0.67, 1.17), 334/3703 Q4 (2.3 [1.2–4.0]): 1.09 (0.83, 1.44), 371/3703 p-trend = 0.57 (non-significant)
WOMAC pain (moderate)			*Quartiles of total fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (8.6 [6.3–11.3]): 1.00 referent, 269/3703 Q2 (12.5 [9.9–15.6]): 0.76 (0.58, 1.02), 240/3703

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
			Q3 (15.2 [12.2–19.0]): 0.70 (0.52, 0.94), 240/3703 Q4 (20.6 [16.2–26.5]): 0.57 (0.42, 0.77), 189/3703 *p*-trend = 0.0004 (significant)
			Quartiles of cereal grain fibre (median [IQR] g/day): OR (95% CI), no. of cases Q1 (3.7 [2.5–5.2]): 1.00 referent, 257/3703 Q2 (5.0 [3.5–6.8]): 1.08 (0.80, 1.45), 242/3703 Q3 (5.7 [3.9–8.0]): 0.91 (0.68, 1.22), 230/3703 Q4 (6.8 [4.5–9.8]): 0.98 (0.73, 1.32), 227/3703 *p*-trend = 0.59 (non-significant)
			Quartiles of fruit and vegetable fibre (median [IQR] g/day): OR (95% CI), no. of cases Q1 (3.8 [2.6–5.4]): 1.00 referent, 268/3703 Q2 (6.1 [4.5–8.1]): 0.93 (0.69, 1.25), 243/3703 Q3 (7.8 [6.0–10.0]): 0.85 (0.63, 1.15), 230/3703 Q4 (10.5 [7.8–14.0]): 0.60 (0.45, 0.81), 199/3703 *p*-trend = 0.0004 (significant)
			Quartiles of legume and nut fibre (median [IQR] g/day):OR (95% CI), no. of cases Q1 (0.8 [0.4–1.4]): 1.00 referent 245/3703 Q2 (1.4 [0.8–2.1]): 0.98 (0.73, 1.32), 242/3703 Q3 (1.6 [1.0–2.6]): 0.92 (0.69, 1.23), 245/3703 Q4 (2.3 [1.2–4.0]): 0.77 (0.57, 1.05), 208/3703 *p*-trend = 0.09 (non-significant)
WOMAC pain (severe)			*Quartiles of total fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (8.6 [6.3–11.3]): 1.00 referent, 108/3703 Q2 (12.5 [9.9–15.6]): 0.59 (0.38, 0.90), 67/3703 Q3 (15.2 [12.2–19.0]): 0.61 (0.39, 0.93), 70/3703 Q4 (20.6 [16.2–26.5]): 0.41 (0.24, 0.68), 53/3703[a] *p*-trend = 0.0006 (significant)
			Quartiles of cereal grain fibre (median [IQR] g/day): OR (95% CI), no. of cases Q1 (3.7 [2.5–5.2]): 1.00 referent, 102/3703 Q2 (5.0 [3.5–6.8]): 1.04 (0.69, 1.57), 84/3703 Q3 (5.7 [3.9–8.0]): 0.65 (0.41, 1.03), 64/3703

(Continues)

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
			Q4 (6.8 [4.5–9.8]): 0.55 (0.33, 0.91), 48/3703 *p*-trend = 0.006 (significant) *Quartiles of fruit and vegetable fibre (median [IQR] g/day): OR (95% CI), no. of cases* Q1 (3.8 [2.6–5.4]): 1.00 referent, 94/3703 Q2 (6.1 [4.5–8.1]): 0.89 (0.57, 1.39), 72/3703 Q3 (7.8 [6.0–10.0]): 0.85 (0.55, 1.33), 67/3703 Q4 (10.5 [7.8–14.0]): 0.61 (0.39, 0.95), 67/3703 *p*-trend = 0.02 (significant) *Quartiles of legume and nut fibre (median [IQR] g/day):OR (95% CI), no. of cases* Q1 (0.8 [0.4–1.4]): 1.00 referent, 104/3703 Q2 (1.4 [0.8–2.1]): 0.60 (0.38, 0.94), 63/3703 Q3 (1.6 [1.0–2.6]): 0.70 (0.46, 1.09), 73/3703 Q4 (2.3 [1.2–4.0]): 0.69 (0.44, 1.09), 56/3703 *p*-trend = 0.23 (non-significant)
Pain worsening	Dai et al. (2017b)[5]	Regression analysis using SAS V.9.3. *Confounders*: Age, sex, race, total energy intake; education attainment, annual household income, smoking status, physical activity and other dietary factors including dietary vitamin C (mg/day), K (μg/day), polyunsaturated fat (g/day), saturated fats, anti-inflammatory drugs use, glycaemic load, DGAI-2010 (Framingham study) and BMI.	*OAI* *Quartiles of total fibre (g/day): OR (95% CI), no. of cases* Q1 (8.6): 1.00 referent, 526/1970 Q2 (12.5): 0.98 (0.87, 1.10), 512/1988 Q3 (15.2): 0.96 (0.84, 1.08), 514/1994 Q4 (20.6): 0.85 (0.74, 0.99), 412/1999 *p*-trend = 0.03 (significant) *OAI* *Quartiles of cereal fibre (g/day): OR (95% CI), no. of cases* Q1 (2.8): 1.00 referent, 554/1975 Q2 (4.5): 0.93 (0.83, 1.04), 474/1974 Q3 (6.0): 0.95 (0.84, 1.07), 480/1998 Q4 (8.4): 0.89 (0.79, 1.01), 456/2004 *p*-trend = 0.07 (non-significant) *OAI* *Quartiles of fruit and vegetable fibre (g/day): OR (95% CI) in OAI, no. of cases* Q1 (3.4): 1.00, referent, 496/1982

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
			Q2 (5.8): 1.00 (0.89, 1.13), 508/1986 Q3 (7.9): 1.03 (0.90, 1.17), 512/1998 Q4 (11.5): 0.95 (0.82, 1.12), 448/1985 *p*-trend = 0.77 (non-significant) *OAI* *Quartiles of nut and legume fibre (g/day): OR (95% CI) in OAI, no. of cases* Q1 (0.5): 1.00, referent, 487/1980 Q2 (1.1): 1.04 (0.93, 1.17), 502/1982 Q3 (1.8): 1.04 (0.92, 1.17), 493/1979 Q4 (3.2): 1.00 (0.88, 1.13), 478/1998 *p*-trend = 0.82 (non-significant)
SxOA knee	Dai et al. (2017b)[5]	Regression analysis using SAS V.9.3. *Confounders*: Age, sex, race, total energy intake; education attainment, annual household income, smoking status, physical activity and other dietary factors including dietary vitamin C (mg/day), K (μg/day), polyunsaturated fat (g/day), saturated fats, anti-inflammatory drugs use, glycaemic load, DGAI-2010 (Framingham study) and BMI.	*Quartiles of total fibre (g/day): OR (95% CI) stratified by study, no. of cases* *OAI* Q1 (8.6): 1.00 referent, 208/1346 Q2 (12.5): 1.14 (0.89, 1.46), 256/1440 Q3 (15.1): 0.81 (0.62, 1.06), 206/1472 Q4 (20.6): 0.80 (0.60, 1.07), 199/1494 *p*-trend = 0.03 (significant) *Framingham study* Q1 (13.7): 1.00, referent, 41/483 Q2 (14.8): 1.03 (0.53, 2.00), 50/488 Q3 (19.1): 0.46 (0.22, 0.95), 24/484[a] Q4 (25.5): 0.39 (0.17, 0.92), 28/486[a] *p*-trend = 0.03 (significant) *Quartiles of cereal fibre (g/day): OR (95% CI) stratified by study, no. of cases* *OAI* Q1 (2.8): 1.00 referent, 211/1348 Q2 (4.5): 1.05 (0.83, 1.34), 226/1420 Q3 (6.0): 1.00 (0.79, 1.28), 215/1450 Q4 (8.4): 0.96 (0.75, 1.24), 217/1534 *p*-trend = 0.79 (non-significant) *Framingham study* Q1 (3.7): 1.00, referent, 38/453 Q2 (4.4): 1.28 (0.70, 2.33), 46/457

(Continues)

TABLE 3 (Continued)

Outcome	Reference (Year), study design, covariates in fully adjusted model	Statistical analyses (methods and confounders)	Outcome result
			Q3 (5.8): 0.62 (0.32, 1.20), 25/454 Q4 (9.7): 0.57 (0.28, 1.17), 26/454 *p*-trend = 0.06 (non-significant) *Quartiles of fruit and vegetable fibre (g/day): OR (95% CI) stratified by study, no. of cases* *OAI* Q1 (3.4): 1.00 referent, 214/1374 Q2 (5.8): 1.00 (0.78, 1.28), 238/1504 Q3 (7.9): 0.89 (0.68, 1.17), 205/1434 Q4 (11.5): 0.83 (0.60, 1.15), 212/1440 *p*-trend = 0.24 (non-significant) *Framingham study* Q1 (3.6): 1.00 referent, 39/453 Q2 (5.8): 0.17 (0.07, 0.44), 16/456[a] Q3 (8.3): 0.80 (0.35, 1.79), 52/453 Q4 (12.8): 0.44 (0.16, 1.23), 28/456 *p*-trend = 0.57 (non-significant) *Quartiles of nut and legume fibre (g/day): OR (95% CI) stratified by study, no. of cases* *OAI* Q1 (0.5): 1.00, referent, 196/1378 Q2 (1.1): 1.08 (0.84, 1.39), 222/1436 Q3 (1.8): 1.08 (0.84, 1.39), 230/1446 Q4 (3.2): 1.03 (0.79, 1.34), 220/1484 *p*-trend = 0.99 (non-significant) *Framingham study* Q1 (0.7): 1.00, referent, 40/453 Q2 (1.6): 0.59 (0.31, 1.14), 37/457 Q3 (2.4): 0.29 (0.14, 0.59), 24/452[a] Q4 (4.4): 0.41 (0.20, 0.82), 34/456[a] *p*-trend = 0.03 (significant)

[a]Data with strong effects.

Abbreviations: aMED, Mediterranean Diet Score; BMI, Body Mass Index; CES-D, Centre for Epidemiologic Studies Depression Scale; CI, confidence interval; DGAI-2010, Dietary Guidelines Adherence Index; E-DII, Energy-Adjusted Dietary Inflammatory Index; g/day, grams per day; JSW, joint space width; KL, Kellgren–Lawrence; KOA, knee osteoarthritis; no., number; OA, osteoarthritis; OAI, osteoarthritis initiative; OR, odds ratio; PASE, physical activity scale for the elderly; QoL, quality of life; RR, relative risk; SAS, statistical analysis software; SxOA, symptomatic osteoarthritis; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

TABLE 4 Joanna Briggs Institute critical appraisal results

	Dai et al. (2017a)[37]	Dai et al. (2017b)[5]	Veronese et al. (2019)[38]	Liu et al. (2020)[34]	Xu et al. (2020)[4]	Ruan et al. (2021)[39]
Were the two groups similar and recruited from the same population?	N	N	N	N	N	N
Were the exposures measured similarly to assign people to both exposed and unexposed groups?	Y	Y	Y	Y	Y	Y
Was the exposure measured in a valid and reliable way?	Y	Y	Y	Y	Y	Y
Were confounding factors identified?	Y	Y	Y	Y	Y	Y
Were strategies to deal with confounding factors stated?	Y	Y	Y	Y	Y	Y
Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?	NA	NA	NA	NA	NA	NA
Were the outcomes measured in a valid and reliable way?	Y	Y	Y	Y	Y	Y
Was the follow up time reported and sufficient to be long enough for outcomes to occur?	Y	Y	Y	Y	Y	Y
Was follow up complete, and if not, were the reasons to loss to follow up described and explored?	Y	Y	Y	Y	Y	Y
Were strategies to address incomplete follow up utilised?	Y	N	N	N	Y	Unclear
Was appropriate statistical analysis used?	Y	Y	Y	Y	Y	Y
Overall	Include	Include	Include	Include	Include	Include

harm, thus were downgraded for serious imprecision.[39] The association between diet quality and total WOMAC and WOMAC physical dysfunction were downgraded due to very serious imprecision, as very wide CIs crossed appreciable benefits, null effects and appreciable harms.[39] The association between poor diet quality and symptomatic osteoarthritis was not downgraded for imprecision as the CI did not cross appreciable harms and null effects.[4] The association between dietary inflammatory potential and symptomatic osteoarthritis was downgraded for serious imprecision due to wide CIs for higher quartiles.[34]

Furthermore, the association between Western dietary patterns and symptomatic osteoarthritis progression was downgraded for imprecision due to wide CIs.[4] The association between Prudent diet and symptomatic osteoarthritis progression was not downgraded for imprecision.[4] The association between the Mediterranean Diet and symptomatic osteoarthritis and pain worsening had no imprecision downgrades, as CIs for all scores crossed the null effect, but did not reach appreciable benefit or harm.[38] The association between each fibre category and mild, moderate and severe knee pain was downgraded for very serious imprecision due to wide CIs.[37] The associations between dietary fibre and incident symptomatic osteoarthritis and pain worsening were not downgraded for imprecision[5].

The eligible studies examined the effect of different dietary patterns or food groups on the progression of symptomatic osteoarthritis or the change of osteoarthritis-specific symptoms within a period of time. Due to the measurement differences of dietary patterns, food groups and outcomes, it was not possible to conduct meta-analysis to pool the data for the overall effect. Therefore, the overall relative risk and CI were not calculated due to the variance of exposure and outcome. Thus, the overall imprecision could not be assessed.

In the included articles, the exposure included either dietary patterns or food groups using different types of food frequency questionnaires, such as Block Brief 2000 food frequency questionnaire,[5,34,37,38] Dietary Questionnaire for Epidemiological Studies v2,[39] 70-item Block Brief food frequency questionnaire.[4] Moreover, the definitions of the outcome varied across all studies, including prevalence of different level of pain,[37] pain and/or function worsening,[4,5,38,39] and new onset of symptomatic osteoarthritis.[5,34,38] As a result, the exposure and the outcome of each article were not able to be compared directly, and the statistical assessment for analysing heterogeneity was not applicable. Therefore, the different effects across studies and the overall inconsistency could not be assessed.

Based on the eligibility criteria, all included articles were strictly aligned with the study question regarding population, intervention/exposure, comparison and

TABLE 5 Assessment of the certainty of the evidence using the GRADE system

Certainty assessment							
No. of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Certainty**
Symptomatic osteoarthritis progression							
4[4,5,34,38]	Observational studies	Serious[a]	Not serious	Not serious	Serious[b]	Dose response gradient	⨁◯◯◯ Very low
Knee pain VAS							
1[39]	Observational studies	Serious[a]	Not serious	Not serious	Serious[c]	None	⨁◯◯◯ Very low
WOMAC joint stiffness							
1[39]	Observational studies	Serious[a]	Not serious	Not serious	Serious[c]	None	⨁◯◯◯ Very low
WOMAC knee pain							
1[39]	Observational studies	Serious[a]	Not serious	Not serious	Serious[c]	None	⨁◯◯◯ Very low
Total WOMAC							
1[39]	Observational studies	Serious[a]	Not serious	Not serious	Very serious[d]	None	⨁◯◯◯ Very low
WOMAC physical dysfunction							
1[39]	Observational studies	Serious[a]	Not serious	Not serious	Very serious[d]	None	⨁◯◯◯ Very low
Pain worsening							
2[5,38]	Observational studies	Serious[a]	Not serious	Not serious	Not serious	Dose response gradient	⨁⨁◯◯ Low
WOMAC pain							
1[37]	Observational studies	Serious[a]	Not serious	Not serious	Serious[e]	None	⨁◯◯◯ Very low

Abbreviation: CI, confidence interval; VAS, Visual Analog Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

[a]Cohort study design without concealment to data analysis, significantly different baseline participant characteristics across exposure groups or no statistical analysis to evaluate baseline participant characteristic differences, and unclear strategies utilised to address incomplete follow up.

[b]The associations between dietary inflammatory potential and symptomatic osteoarthritis and Western diet intake and symptomatic osteoarthritis, were downgraded for serious imprecision due to wide confidence intervals which include appreciable harm. The association between poor diet quality and symptomatic osteoarthritis was not downgraded for imprecision as the confidence interval did not cross appreciable harms and null effects. The association between Prudent diet and symptomatic osteoarthritis progression, between the Mediterranean Diet and symptomatic osteoarthritis, and between and dietary fibre and symptomatic osteoarthritis had no imprecision downgrades, as confidence intervals for the highest adherence of those diet did not cross appreciable benefit or harm.

[c]Serious imprecision due to wide confidence intervals spanning appreciable benefit and harm.

[d]Very serious imprecision due to very wide confidence intervals crossed appreciable benefits, null effects and appreciable harms.

[e]The association between each fibre category and mild, moderate and severe knee pain was downgraded for very serious imprecision due to wide confidence intervals.

outcomes (PICO). Hence, the evidence in included papers can apply and address the research question of this systematic review, suggesting little indirectness.

The results of the included articles presented positive, null and negative effects for different dietary patterns, so the publication bias was considered as undetected. However, publication bias cannot be ruled out as only articles in English were eligible for this systematic review. There may be non-English studies that complied with the inclusion criteria, however, were excluded due to the limitation of reading other languages.

4 | DISCUSSION

This systematic review consolidates available evidence on the associations between dietary habits, diet quality, food groups and symptomatic osteoarthritis in adults aged 45 years and older with joint pain, aching or stiffness. Poor diet quality was associated with accelerated symptomatic osteoarthritis progression,[4] whereas healthy diets aligned with the Dietary Guidelines for Australian Adults and Australian Guide to Healthy Eating had an inconclusive effect.[39]

In terms of dietary pattern, diets with a higher inflammatory potential were linked to a higher incidence of symptomatic osteoarthritis.[34] The Western pattern had an increased effect on symptomatic osteoarthritis advancement, whereas the Prudent pattern had a reduced effect.[4] The Mediterranean dietary pattern reduced knee symptomatic osteoarthritis progression and pain worsening.[38] In addition, total dietary fibre and fibre from different food groups had null, reduction and inconclusive effects on pain worsening in different pain categories.[5,37]

Only six articles from three cohort studies were included. The certainty of the body of evidence ranged from low to very low and is limited. As highlighted, little is known about diet quality in individuals with osteoarthritis and its interrelationship with pain, physical dysfunction and quality of life,[42] indicating a need for additional research of a higher certainty of evidence.

Two studies explored associations between overall diet quality and symptomatic osteoarthritis, however, were inconsistent. One study found no significant association between diet quality and symptomatic osteoarthritis,[39] while the other study found a positive association between poor diet quality and symptomatic osteoarthritis.[4] The inconclusive results could be attributed to a few factors, one being the different sample size (392 participants in VIDEO[39] against 2757 participants in American Osteoarthritis Initiative[4]). The other factor could be the variation in how diet quality score is calculated. One study included alcohol when calculating the diet quality score,[39] whereas the other adjusted alcohol intake as a confounder.[4] A systematic review suggested alcohol may contribute to osteoarthritis via the mediation of BMI, despite its inconclusive effects.[43]

The Western dietary pattern was positively associated with progression of symptomatic osteoarthritis.[4] The Western diet is abundant in saturated fat intake, which promotes white adipose tissue expansion and adipocyte dysfunction.[44,45] In addition, high energy and high refined carbohydrate intake are also the main components of the Western Diet.[44] These components contribute to the enhancement of inflammatory signalling and activation of inflammatory gene expression, hence increasing inflammation.[44,45] A prior study established a strong positive correlation between Western dietary patterns and the dietary inflammatory index.[46] Greater dietary inflammatory Index scores are linked with increased weight gain, obesity risk,[47] greater pain severity[42] and knee osteoarthritis prevalence.[34] However, associations between DII and symptomatic osteoarthritis may not entirely be accounted for via effect on BMI, and is potentially mediated via inflammatory markers.[34,48] Therefore, the Western diet and the pro-inflammatory diet may have similar mechanisms in accelerating osteoarthritis progression. However, additional research is needed to determine the degree of impacts of the Western diet and diets with high inflammatory potential using consistent symptomatic osteoarthritis outcome assessments. These include using WOMAC pain or pain improvement scores, or the same definition of symptomatic osteoarthritis, such as using the WOMAC score.

One study explored Mediterranean diet associations on symptomatic osteoarthritis and pain worsening,[38] overall drawing inconclusive effects. Increased adherence to a Mediterranean diet may alleviate osteoarthritis symptoms by lowering serum levels of pro-inflammatory cytokines and other mediators, such as high-sensitivity C-reactive protein, interleukins 6, 7 and 18, as well as decreasing oxidative stress biomarkers.[49–51] Thus, reducing these biomarkers slows cartilage degeneration.[7,52,53] Greater Mediterranean Diet scores were associated with reduced inflammation,[50,54] oxidative stress[47] and greater fibre and vitamins, which may exhibit a protective effect on osteoarthritis outcomes.[5] The protective effects of the Mediterranean diet on the prevalence of osteoarthritis were shown in a previous systematic review with a fair risk of bias in middle-aged adults and the elderly with or at risk of osteoarthritis.[33]

The Prudent diet drew decreased effects on symptomatic osteoarthritis. The protective benefits of the Prudent dietary pattern on the risk of knee osteoarthritis were explored in adults aged over 45 years at a good quality in a previous systematic review.[32] This study[32] was a meta-analysis exploring associations between general symptomatic osteoarthritis, knee osteoarthritis and dietary patterns. It included only one article, which had symptomatic osteoarthritis as a primary outcome. Given the main aim of this research investigating dietary patterns and symptomatic osteoarthritis, the current study's results will add further value to the previous meta-analysis.[32]

Dietary components of the Prudent diet are similar to that of the Mediterranean diet, generally including high consumption of vegetables, fruits, fish, whole grains and legumes.[39] In addition, high adherence to a prudent diet was negatively associated with systemic inflammatory biomarkers, such as leptin, soluble intracellular adhesion molecule 1, E-selectin and C-reactive protein.[55,56] As such, the causes for the preventive effects of decreasing symptomatic osteoarthritis progression of the Prudent diet may be similar to those of the Mediterranean diet via similar mechanisms explained above.

Two studies examined the associations between dietary fibre intake and symptomatic osteoarthritis.[5,37] The protective effects of total fibre consumption were constant across both studies with a significant dose-dependent downward trend, however, the effects of fibre from

each food group were inconclusive. The protective effects of dietary fibre are regulated by its fermentation products, short chain fatty acids.[57] Short chain fatty acids inhibit inflammatory responses by activating G Protein-coupled Receptor,[58] which has anti-inflammatory properties, and by suppressing the expression of pro-inflammatory cytokines.[57,59] One study discovered that fruit and vegetable fibre were inversely associated with moderate knee pain and cereal fibre and fruit and vegetable fibre were inversely associated with severe knee pain,[37] whereas the other failed to demonstrate significant effects of fibre from each food group.[5] One study included an additional adjustment for BMI,[5] whilst the other did not.[37] Another argument could be that categorising pain levels allows for more precise outcomes, as the magnitude of positive effects may be diluted in the absence of pain classification. One study[37] explored fibre intake effects on mild, moderate and severe pain, whilst one investigated effects on overall pain.[5] Moreover, increased total fibre, and nut and legume fibre, were found to be inversely associated with incidence symptomatic osteoarthritis in the Framingham study, such effects attenuated in American Osteoarthritis Initiative.[5] The discrepancy could be explained by the fact that American Osteoarthritis Initiative and the Framingham trial had different sample sizes, participant characteristics, especially that the American Osteoarthritis Initiative cohort had a higher mean BMI than Framingham Study participants, raising collider bias potential via conditioning on BMI, and dietary fibre quartile cut-offs and the Framingham study measured dietary consumption 4 years later at follow-up. Slight intake increments present in the study sample over the follow-up were unaccounted for in the American Osteoarthritis Initiative cohort.[37] Furthermore, additional research focusing on dietary fibre intake and associations with symptomatic osteoarthritis in adults 45+ year would be beneficial to raise the certainty of the body of evidence.

In contrast to previous review studies, the present systematic review focused exclusively on symptomatic osteoarthritis as the outcome. The findings indicate that diet quality, dietary patterns and food groups influence not just radiographic osteoarthritis progression, but also symptomatic osteoarthritis progression. Many previous studies explored nutrient and symptomatic osteoarthritis associations, with single dietary components failing to be corroborated in randomised trials.[20] Review strengths included the large sample size of the six articles, PROSPERO registration to allow method transparency, a comprehensive search strategy that was reviewed by supervisors and University of Sydney librarians, and included five databases. Authors were contacted to access full-text of articles. Quality assessment tools enabled risk of bias assessment for cohort studies using Joanna Briggs Institute checklists. Certainty of the evidence for dietary patterns and outcomes were assessed using GRADE.

However, there were limitations. Bi-direction via meta-analysis could not be explored due to the few included studies and heterogeneity of exposure and outcome measurements. A range of dietary patterns and food groups were included using different measuring methods. Despite the fact that all dietary intake measurement methods are validated, their accuracy may be varied. Knee pain assessment heterogeneity between studies may also hinder the review's accuracy of findings. Frequent knee pain was defined as pain, aching or stiffness in the knee on most days during the past 30 days,[5,38] whilst one study queried whether participants had experienced this over the past 12 months.[34] Large effects were identified as more than 50% of protective effects observed for dietary patterns on symptomatic osteoarthritis outcomes. Upgrading the certainty of evidence in this review was prohibited due to concerns about risk of bias and imprecision.[60,61] The risk of bias of the included studies cannot be eliminated due to potential residual confounders in the observational studies, such as BMI,[34,37] alcohol[5,34,37,39] and depression,[5,34,39] cohort study design, significant differences among baseline participant characteristics baseline and unclear strategies addressing loss to follow up. Additionally, studies merely assessed baseline dietary intake, with the exception of the Framingham study.[5] Under- or overestimation of dietary intake can occur due to self-reported dietary data prone to bias.[62] Cohort studies are observational studies that do not prove causality, raising residual confounding concerns.[5] They merely provide empirical evidence, and results should be confirmed by studies at higher certainty of evidence.

There are limitations regarding search strategy, language and practicality. This systematic review included only English-language articles and lacked exhaustive search strategies for trial registries and grey literature from websites and organisations. Additionally, despite attempts to contact authors for full-text retrieval, certain articles were excluded due to author non-response. Therefore, it is plausible that certain pertinent articles may be omitted. Furthermore, studies involving intervention via energy restriction were not included. This is because the effect of diet is difficult to distinguish from the effect of weight loss. Finally, because all six studies involved participants with osteoarthritis and were conducted in developed countries, the findings of this systematic review may not be generalisable to non-American Osteoarthritis Initiative populations as dietary patterns vary by ethnic and environmental backgrounds.

As shown by the results of the six reviewed studies, associations were identified between dietary intake, diet

quality, food groups and symptomatic osteoarthritis in adults aged 45 years and older. Participants following a higher prudent dietary pattern had the greatest symptomatic osteoarthritis reduction. The currently limited body of evidence due to low certainty attributable to heterogeneity and study limitations suggest that there is a knowledge gap regarding the association between diet and symptomatic osteoarthritis. Further research is warranted to confirm the estimated effects at a high certainty of evidence, and to investigate the effects of other dietary patterns and food groups on symptomatic osteoarthritis, such as DASH. Identifying the most effective dietary patterns may aid in the development of future symptomatic osteoarthritis management guidelines.

AUTHOR CONTRIBUTIONS

AD and VH conceptualised the systematic review. DF and JZ contributed to literature search screening, data extraction, quality assessment and draft manuscript. VH and AD contributed to initial research question development, methodology, quality assessment and data extraction, as well as providing critical feedback on the manuscript. The final manuscript was reviewed and approved by all authors. The authors acknowledge the University of Sydney Librarians for their assistance with reviewing databases and the search strategy.

CONFLICT OF INTEREST

Vasant Hirani is Associate Editor of Nutrition & Dietetics. They were excluded from the peer review process and all decision-making regarding this article. This manuscript has been managed throughout the review process by the Journal's Editor-in-Chief. The Journal operates a blinded peer review process and the peer reviewers for this manuscript were unaware of the authors of the manuscript. This process prevents authors who also hold an editorial role to influence the editorial decisions made. Other authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Zeng J, Franklin DK, Das A, Hirani V. The effects of dietary patterns and food groups on symptomatic osteoarthritis: A systematic review. *Nutrition & Dietetics*. 2023;80(1):21-43. doi:10.1111/1747-0080.12781

Received: 18 March 2022 | Revised: 27 July 2022 | Accepted: 9 August 2022

DOI: 10.1111/1747-0080.12770

Nutrition & Dietetics Journal of Dietitians Australia WILEY

REVIEW

The effect of oral refeeding compared with nasogastric refeeding on the quality of care for patients hospitalised with an eating disorder: A systematic review

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Funding information
Open access publishing facilitated by La Trobe University, as part of the Wiley - La Trobe University agreement via the Council of Australian University Librarians.

Abstract

Aim: The aim of this systematic review was to compare the benefits and harms of nasogastric and oral-based refeeding on the quality of care, including effectiveness, safety, and patient experience, for patients hospitalised with an eating disorder.

Methods: A systematic search for studies measuring comparative data between nasogastric and oral refeeding methods was conducted in August 2021. Title and abstracts and remaining full texts were screened by both authors. Risk of bias was evaluated using the PEDro scale, and overall quality of evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluation narrative synthesis.

Results: Seven studies (one randomised controlled trial, five non-randomised studies of interventions, and one qualitative study) with 917 participants were included. There was low certainty evidence that nasogastric refeeding resulted in no difference or a small increase in weekly weight gain, and moderate certainty of greater total weight gain, and very low certainty of increased length of stay compared to oral refeeding. There was no difference or a small increase in discharge weight and body mass index with nasogastric refeeding compared to oral refeeding. No serious adverse events were reported.

Conclusion: Patients selected for nasogastric refeeding have a longer duration of illness and lower admission weight, making it difficult to determine which refeeding approach is superior. However, the lack of clear difference in weekly weight gain and the lack of reported harms suggests that other factors such as the normalisation of eating behaviour may be taken into account when choosing the most appropriate refeeding method.

KEYWORDS

anorexia nervosa, eating disorders, enteral feeding, nasogastric feeding, oral feeding

1 | INTRODUCTION

The primary goal of hospitalisation for people with restrictive eating disorders is to promote medical stability by reversing the complications associated with malnutrition, with a secondary goal of normalising eating behaviours.[1] With the focus of nutritional rehabilitation to restore physiological stability through weight gain,[2] 'start low and go slow' approaches to refeeding were initially thought to be the safest way to commence nutritional support.[3,4] The overall goal of the hypocaloric protocols was to avoid refeeding syndrome. Refeeding syndrome can be defined as the life-threatening shifts in electrolytes that can occur when nutrition is reintroduced, with hypophosphatemia being the hallmark electrolyte.[5] Despite earlier concerns, evidence has emerged that higher energy refeeding can safely maximise weight gain throughout hospital admission without the associated complications with refeeding syndrome.[2,3]

While concerns about higher energy refeeding appear to have been resolved, the most appropriate method of refeeding has not. There are two main methods to refeeding this population group, (1) via a nasogastric tube or (2) orally with food or oral nutrition support supplements. Nasogastric refeeding, otherwise referred to as enteral feeding, has been suggested as a lifesaving treatment when patients are physically unwell.[6] Nasogastric feeding involves insertion of a fine bore tube being passed via the nasal passage and into the stomach to provide nutrition.[7] Provision of nasogastric feeding can be delivered in different ways, either as a large bolus via gravity feeding or via a pump, continuously over a 24-h period via a pump or provided intermittently overnight to supplement daytime oral intake.[6] Oral refeeding, otherwise known as meal-based feeding, is where energy intake is provided via oral intake alone without the use of a nasogastric tube.

There may be positive and negative outcomes associated with both nasogastric refeeding and oral refeeding. Nasogastric refeeding may be hypothesised to lead to more rapid weight gain than oral refeeding as energy intake can be more accurately controlled. Nasogastric refeeding can also be viewed as being necessary for some patients as they may lack the psychological capacity to eat.[8] One negative effect with nasogastric refeeding is that a person may feel disempowered and there may be a level of increased reliance with this feeding method.[9] In contrast, oral refeeding increases the opportunity to normalise eating behaviours and challenges unhelpful coping strategies. It can also provide the patient with insight into the required amount of food necessary for weight gain and weight maintenance.[10] However, with less energy intake control by health professionals oral refeeding may not be as effective in achieving rapid weight gain.

A key gap in the literature is that there is no consensus or guidance about which refeeding approach is superior. No previous systematic reviews were located that have directly compared the outcomes between nasogastric and oral refeeding methods. Current literature supports nasogastric refeeding as being an effective and safe method to increase energy intake and rate of weight gain for those individuals with anorexia nervosa.[6,11] One systematic review[3] examined different approaches to refeeding in patients with anorexia nervosa individually but did not directly or quantitatively compare the different approaches.

This systematic review evaluated the benefits and harms of nasogastric refeeding compared with oral refeeding for patients hospitalised with an eating disorder. Benefits and harms will be evaluated in terms of quality-of-care outcomes of effectiveness, safety, and patient experience.

2 | METHODS

This review is reported consistent with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[12] A literature search was conducted on electronic databases: MEDLINE (Ovid), EMBASE (Ovid), CINAHL (EBSCO) and PsycINFO (Ovid) from the earliest available time to 8th August 2021. Relevant keywords related to the construct of 'anorexia nervosa' in combination with Medical Subject Headings (MeSH) terms ('Anorexia Nervosa' or 'Eating Disorder or 'Feeding Disorder' or 'Bulimia Nervosa') were used in combination with words relating to hospitalisation ('Nutritional Therapy' or 'Oral Refeeding' or 'Refeeding' or 'Nasogastric Feeding' or 'Enteral Nutrition' or 'Nasogastric Tube Feeding'). The search was limited to human subjects (see Supporting Information S1). The search was not limited to English language. Database searching was supplemented by searching reference lists of included articles (backward citation) and forward citation tracking via Google Scholar. The systematic review was registered prospectively on PROSPERO [CRD42021274787].

To be eligible for inclusion, participants needed to be adolescents or adults with a diagnosis of anorexia nervosa or bulimia nervosa as diagnosed by DSM-5 criteria[13] managed in a hospital setting. Studies needed to include comparisons between the interventions of nasogastric feeding via a nasogastric tube and oral refeeding via oral food or a structured meal plan. Participants in the nasogastric refeeding group had to rely on this feeding method as their main source of nutrition during hospital admission. There was no limitation on the duration of nasogastric feeding or type of nasogastric feeding such as

intermittent, continuous, or bolus feeding. Studies that reported on parenteral nutrition were excluded. Studies were required to report on outcomes of both nasogastric refeeding and oral refeeding and were required to draw comparisons between the two feeding methods. Outcomes needed to be reported on at least one of: patient effectiveness (e.g., weight gain), harms (safety and adverse events), health service outcomes (e.g., length of stay), or patient/carer perspectives. Studies were excluded if they only reported on refeeding syndrome guidelines and titration of feeding patients with anorexia nervosa. There was no restriction on study design including quantitative and qualitative studies provided comparative data was presented (see online supplementary Appendix S1).

After downloading the results of the search strategy into Covidence,[14] the inclusion and exclusion criteria were applied to titles and abstracts by two reviewers independently. If deemed potentially eligible the full text publication was retrieved and reviewed by two review authors independently to determine eligibility for inclusion of articles for the final analysis. Contrasting opinions regarding eligibility were resolved by discussion until consensus was achieved. Agreement between reviewers was described with kappa (κ).[15] Where κ equaled between 0.00 and 0.20 this indicates slight agreement; 0.21 and 0.40 indicates fair agreement; 0.41 and 0.60 indicates moderate agreement; 0.61 and 0.80 indicates substantial agreement; 0.81 and 1.00 indicates almost perfect agreement.[16]

Nasogastric refeeding and oral refeeding intervention data were extracted and described according to the template for intervention description and replication (TIDieR) checklist.[17] Quality of care outcomes were grouped into four categories and data extracted on: (1) patient outcomes: weekly weight gain, total weight gain, discharge weight, and discharge body mass index; (2) health service outcomes: length of stay, and hospital readmissions; (3) safety outcomes: mortality rate, bradycardia defined as heart rate below 50 bpm, hypotension defined as systolic blood pressure <90 mmHg, oedema or swelling, gastrointestinal outcomes including nausea, vomiting, diarrhoea, bloating and non-life-threatening complications including epistaxis or nasal irritation; (4) patient or carer experience including adherence to treatment.

Quantitative studies were assessed by two reviewers, who independently rated the 10 criteria on the PEDro scale as yes or no. One criteria relates to external validity; the remaining 10 criteria relate to internal validity and contribute to one point each, if the criterion is met, then one point is given to provide a score out of 10. The PEDro scale is a valid measure of internal validity.[18] Studies scoring <6 were deemed to be of low quality. Qualitative studies were assessed by the Critical Appraisal Skills Programme tool.[19] Criteria related to validity of study design, clinical relevance of the study and nature of results.

Qualitative data were synthesised descriptively. Quantitative data were presented as the post-intervention mean ± SD for nasogastric and oral refeeding groups. Where not reported, the standard deviation of weight change was estimated according to recommendations,[20] based on the standard deviation of the baseline measure of weight and the retest reliability of measuring weight ($r = 0.99$).[21] As meta-analysis was unable to be conducted, pooled data between studies was removed and standardised mean difference and 95% confidence intervals (CI) were presented as forest plots for each outcome. Quantitative data were synthesised using a narrative approach[22] as meta-analyses are not recommended for reviews combining both randomised controlled trials and non-randomised studies of interventions.[23] Certainty of evidence was evaluated using a Grading of Recommendations, Assessment, Development and Evaluation narrative approach.[22] The process involved downgrading studies from high to moderate to low to very low certainty of evidence based on the following domains: (1) methodological limitation of the studies, if the PEDro score was <6 for the majority of studies (>50%) of studies, (2) indirectness, if there was variability in the intervention and outcome measure compared to the research question, (3) imprecision, when CIs of all the studies or of the largest studies included no effect and clinically meaningful benefits or harms, (4) inconsistency, evaluated by the consistency and direction and difference in the magnitude of effects across studies, and (5) publication bias, studies were downgraded if the body of evidence consists of only small positive studies.

3 | RESULTS

Figure 1 shows the results of the study selection process. After removal of duplicates and screening of original search yield of 2157 citations, 20 articles were reviewed in full text and 13 were excluded resulting in seven included studies. Agreement between reviewers on application of inclusion criteria to title and abstracts was fair ($\kappa = 0.257$, 95% CI 0.128 to 0.386) and moderate for full texts ($\kappa = 0.588$, 95% CI 0.235 to 0.940). No comparisons between nasogastric and oral refeeding methods ($n = 11$), wrong comparator ($n = 1$) and wrong outcomes, that is, refeeding syndrome with no discussion around feeding methods ($n = 1$) were the main reasons for exclusion.

Characteristics of included studies are summarised in Tables 1 and 2. The seven studies included in this review

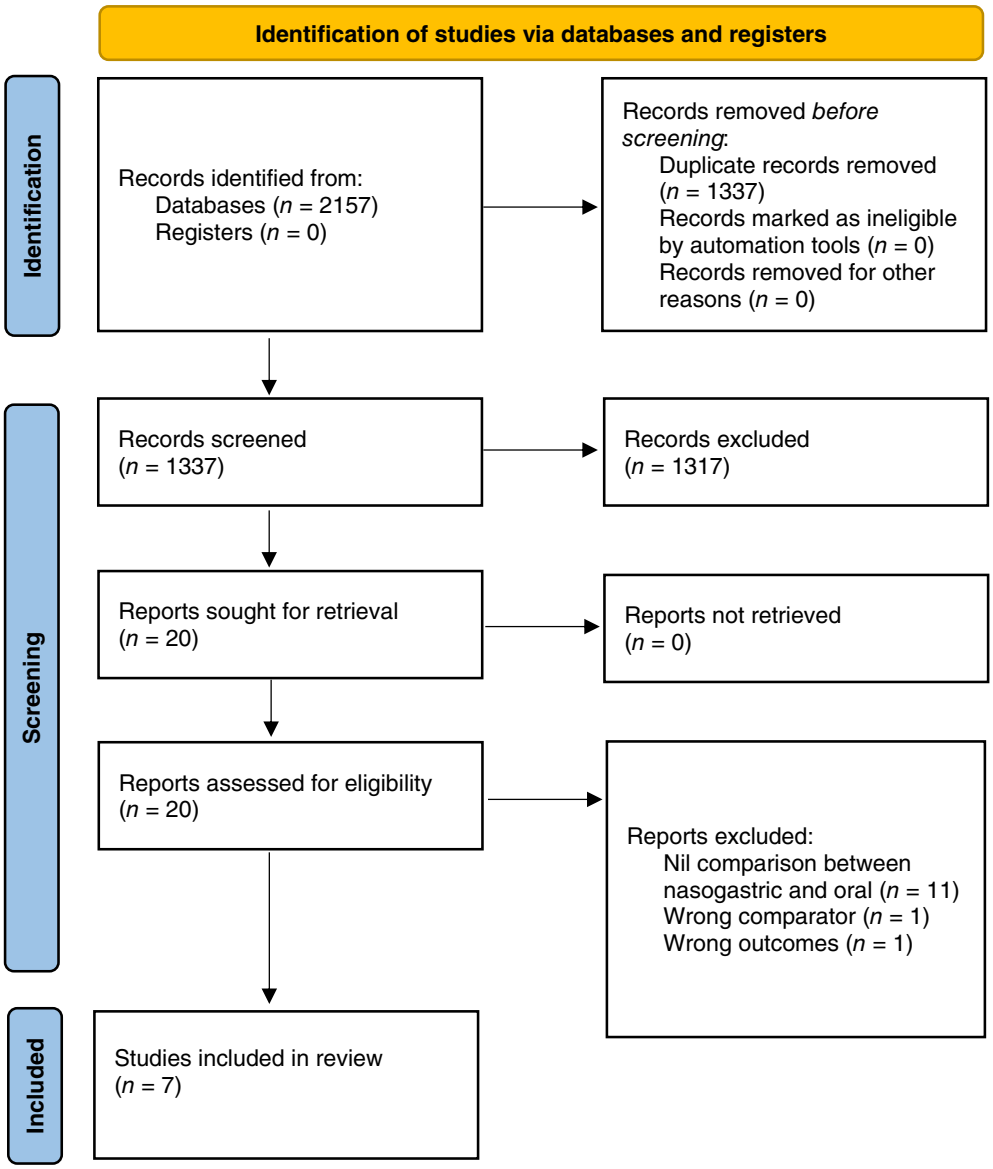

FIGURE 1 Flowchart illustrating the literature search and selection process

represent a total of 917 participants, with sample sizes ranging from 6 to 226 participants.

One study was a randomised controlled trial, which compared the efficacy of nasogastric refeeding and oral refeeding over a 2-month period.[24] Five studies were non-randomised studies of interventions reporting on comparisons between nasogastric and oral refeeding methods.[25–29] Three of the non-randomised studies were conducted retrospectively via medical or file reviews.[25,27,28] Two of the non-randomised studies retrospectively collected data and contacted patients via mail to complete questionnaires to assess recovery from the psychological aspects of anorexia nervosa.[26,29] The final study was qualitative in study design and reported on patient or carer experiences of nasogastric and oral refeeding in hospital.[30] Patient and carer experience was explored by completion of semi-structured self-report questionnaires, which were analysed inductively.

All seven studies reported on patients diagnosed with anorexia nervosa.[24–30] Duration of illness was longer in the nasogastric refeeding group compared to the oral refeeding group (nasogastric refeeding weighted mean average 7.3 years, oral refeeding weighted mean average 7.2 years).[24,25,29] One study commenced patients on continuous nasogastric feeds,[25] while four studies used intermittent or overnight nasogastric feeds.[24,27–29] Two studies did not report on the nasogastric feeding mode or regimen.[26,30] Three studies reported on structured meal plans as the mode of oral refeeding,[24,25,27] while the remaining four studies did not report on oral refeeding mode or regimen.[26,28–30] Duration of nasogastric refeeding was reported in four studies.[23–26] Duration varied between the four studies; two studies reported an average of 36 days was

TABLE 1 Summary of study characteristics

Study	Study design	Sample size	Age (y), mean (SD)	Weight on admission (kg)	Gender (% F)	Diagnosis	Duration of illness (y), mean (SD)
Gentile et al. (2008)	Non-randomised intervention	*NG* (*n* = 32) *OR* (*n* = 43)	*NG* 21.8 ± 9.1 *OR* 18.9 ± 6.2	*NG* 31.9 ± 4.8 *OR* 32.7 ± 5.2	Not reported	AN	*NG* 3.8 ± 3.4 years *OR* 3.04 ± 3.5 years
Neiderman et al. (2000)	Qualitative study	27 patients	*Not reported*	*Not reported*	93	AN	*Not reported*
Nehring et al. (2014)	Non-randomised intervention	*NG* (*n* = 71) *OR* (*n* = 137)	*NG* 14.3 ± 1.6 *OR* 15.3 ± 1.6	*Not reported*	NG (100) OR (100)	AN	*Not reported*
Rigaud et al. (2007)	Randomised control trial	*NG* (*n* = 41) *OR* (*n* = 40)	*NG* 22.5 ± 4.5 *OR* 24.2 ± 3.8	*NG* 34.0 ± 3.9 *OR* 34.7 ± 4.3	NG (97) OR (98)	AN	*NG* 4.5 ± 1.9 years; *OR* 3.2 ± 2 years
Robb et al. (2002)	Non-randomised intervention	*NG* (*n* = 52) *OR* (*n* = 48)	*NG* 14.8 ± 1.9 *OR* 15.0 ± 1.8	*NG* 41.1 ± 4.7 *OR* 42.5 ± 7.6	NG (100) NG (100)	AN	*Not reported*
Silber et al. (2004)	Non-randomised intervention	*NG* (*n* = 6) *OR* (*n* = 8)	*NG* 13.8 ± 2.0 *OR* 14.9 ± 1.7	*NG* 42.9 ± 10.7 *OR* 46.2 ± 11.0	NG (0) OR (0)	AN	*Not reported*
Zuercher et al. (2003)	Non-randomised intervention	*NG* (*n* = 155) *OR* (*n* = 226)	*NG* 25.7 ± 9.6 *OR* 25.2 ± 8.4	*Not reported*	NG (100); OR (100)	AN	*NG* 8.8 ± 8.5 years; *OR* 8.7 ± 7.8 years

Abbreviations: AN, anorexia nervosa; BMI, body mass index; LOS, length of stay; NG, nasogastric; OR, oral refeeding.

required[24,25]; one study reported 22 days[23]; and one study reported 60 days.[26] Two studies did not report on the duration of nasogastric feeding.[21,22] Duration of oral refeeding was reported across five studies with duration of oral feeding varying across all five studies (22–162 days).[25,26,28,29,31]

Results of the quality assessment are summarised in online supplementary Appendix S2. Five studies received a low rating scoring less than 6 and were considered to be of lower methodological quality.[25–29] One study, a randomised controlled trial, received a score greater than 6 on the PEDro scale and was considered to be of higher methodological quality.[24] One study identified their method of randomisation, which was completed by using sealed envelopes with random numbers corresponding to one regimen.[24] A lack of blinding of participants, assessors and data collectors was the main source of bias with no study adhering completely to the three components of these criteria. All studies completed intention-to-treat analyses and had a dropout less than 15% of participants. One study was evaluated using the 10-point CASP tool for qualitative studies.[30] The study reported on aims, methodological qualities and recruitment of participants in the study. Data collection, analysis and value of research were not reported.

Narrative synthesis of five studies[24,25,27–29] provided low certainty evidence suggesting no difference or a small increase in weekly weight gain favouring nasogastric refeeding compared with oral refeeding (Table 3). Both groups in all five studies achieved mean weekly weight gains of at least 0.5 kg per week (Figure 2).

Narrative synthesis of five studies[24,25,27–29] provided moderate certainty evidence that nasogastric refeeding resulted in more total weight gain than oral refeeding (Table 3). All five studies reported a higher total weight gain in the nasogastric refeeding group compared to the oral refeeding (online supplementary Appendix S3).[24,25,27–29] Nasogastric refeeding weight gain ranged from 5.4 to 15.9 kg compared to the oral refeeding group which ranged from 2.4 to 14 kg. All five studies reported a lower weight on admission for the nasogastric refeeding group compared to the oral refeeding group.

Narrative synthesis of five studies[24,25,27–29] provided very low certainty evidence of no difference in discharge weight (Table 3). One study found an increase in discharge weight with oral refeeding,[29] one study found an increased discharge weight with nasogastric refeeding[24] and three studies found no difference between the two methods of refeeding (online supplementary Appendix S4).[24,26,27] Narrative synthesis of five studies[25–29] provided low certainty evidence of no difference or a small increase in discharge body mass index with nasogastric refeeding at discharge (Table 3). Two studies reported a higher discharge body mass index at discharge with nasogastric refeeding[24,27] and three

TABLE 2 Summary of intervention characteristics

		Nasogastric refeeding			Oral refeeding			
Study	**Setting**	**Description (continuous and intermittent)**	**Initial energy prescription (kJ)**	**Advancement of energy prescription (kJ)**	**Description**	**Initial energy prescription (kJ)**	**Advancement of energy prescription (kJ)**	**Compliance reported (Y/N)**
Gentile et al. (2008)	Medical ward (with specialised eating disorder service)	Continuous NG feeding	*Not reported*	*Not reported*	Structured meal plans	*Not reported*	*Not reported*	Y
Nehring et al. (2004)	Adolescent psychiatric ward	*Not reported*	*Not reported*	*Not reported*	*Not reported*	*Not reported*	*Not reported*	N
Rigaud et al. (2007)	Medical ward (with specialised eating disorder service)	Intermittent NG feeding during the day	2100 kJ	Titrated by 1050 kJ per day until day 14	Structured meal plan	4180 kJ/day	Titrated 1050–2100 kJ per week until day 28.	N
Robb et al. (2002)	Adolescent medical ward until medical stability and patients transferred to adolescent psychiatric unit	Intermittent NG feeding overnight	2500 kJ	Titrated to 4520 kJ at Day 2 and titrated to 5020 kJ at Day 3	Structured meal plan	*Not reported*	*Not reported*	Y
Silber et al. (2004)	Adolescent psychiatric ward	Intermittent NG feeding overnight	*Not reported*	*Not discussed*	*Not reported*	*Not reported*	*Not reported*	N
Zuercher et al. (2003)	Medical ward (with specialised eating disorder service)	Intermittent NG feeding overnight Continuous feeds over 20–24 h period in higher risk patients	*Not reported*	Titrated 1255 kJ every 3 days	*Not reported*	*Not reported*	*Not reported*	N

Abbreviation: NG, nasogastric.

TABLE 3 Summary of findings and certainty of evidence

Question: What is the effect of oral refeeding compared with nasogastric refeeding on the quality of care for hospitalised eating disorder patients?										
Setting: Hospital										
Certainty assessment							**No. of patients**			
No. of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Nasogastric feeding**	**Oral refeeding**	**Effect**	**Certainty**
Weight gain per week (kg)										
5	One randomised control trial and four non-randomised studies of interventions	PEDro score was <6 for the majority of studies (>50%) of studies	Inconsistency in direction and difference in the magnitude of effects across studies	Not serious	Not serious	None	246	365	No difference or a small increase of weight per week favouring nasogastric refeeding Both groups in all five studies achieved mean weekly weight gains of at least 0.5 kg per week	⨁⨁◯◯ Low
Total weight gain (kg)										
5	One randomised control trial and four non-randomised studies of interventions	PEDro score was <6 for the majority of studies (>50%) of studies	Not serious	Not serious	Not serious	None	286	365	All studies reported a higher total weight gain in the nasogastric refeeding group	⨁⨁⨁◯ Moderate
Discharge weight (kg)										
5	One randomised control trial and four non-randomised studies of interventions	PEDro score was <6 for the majority of studies (>50%) of studies	Inconsistency in the magnitude of effects across studies	Not serious	Large confidence intervals in the largest studies	None	286	365	No difference in discharge weight	⨁◯◯◯ Very low

TABLE 3 (Continued)

Question: What is the effect of oral refeeding compared with nasogastric refeeding on the quality of care for hospitalised eating disorder patients?										
Setting: Hospital										
Certainty assessment							**No. of patients**			
No. of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**Nasogastric feeding**	**Oral refeeding**	**Effect**	**Certainty**
Discharge body mass index (kg/m^2)										
5	One randomised control trial and four non-randomised studies of interventions	PEDro score was <6 for the majority of studies (>50%) of studies	Inconsistency in direction and difference in the magnitude of effects across studies	Not serious	Not serious	None	202	276	No difference or a small increase in discharge body mass index with nasogastric refeeding	⨁⨁◯◯ Low
Length of stay (days)										
5	Five non-randomised studies of interventions	PEDro score was <6 for the majority of studies (>50%) of studies	Inconsistency in direction and difference in the magnitude of effects across studies	Not serious	Large confidence intervals in the largest studies	None	316	462	No difference or a moderate to large increase in length of stay with nasogastric refeeding	⨁◯◯◯ Very low

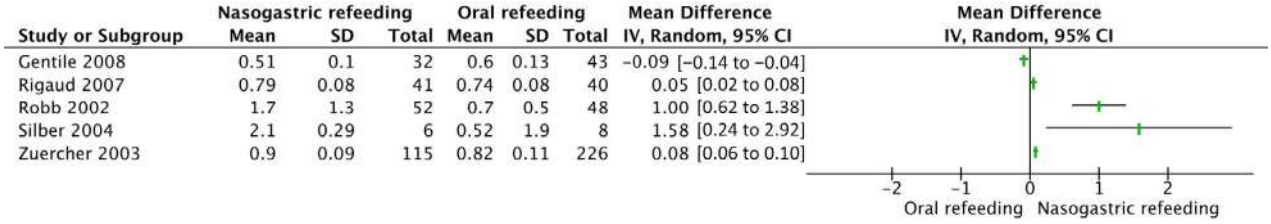

FIGURE 2 Forest plot for total weight gain per week (kg) between nasogastric refeeding compared to oral refeeding

studies found no difference between the two methods of refeeding (online supplementary Appendix S5).[16,17,20]

No studies reported on mortality rate, risk of refeeding syndrome or risk of hypophosphatemia between groups during hospital admission. Non-life threatening medical complications were reported in three studies.[24,27,29] There were no differences in gastrointestinal complications reported in two studies,[24,29] while, three studies reported on a small number of cases of nasal irritation associated with nasogastric tube insertion.[24,27,29] Four studies did not report on any medical adverse events or non-life threatening complications.[25,26,28,30]

Descriptive synthesis of five studies[25–29] provided very low certainty evidence that nasogastric refeeding resulted in no difference or moderate to large increase in length of stay compared to oral refeeding (online supplementary Appendix S6). Mean length of stay ranged from 22 to 219 days in the nasogastric refeeding group compared 22 to 162 days in the oral refeeding group. No studies reported on hospital readmissions.

One study reported on the patient and carer perspective.[30] The use of nasogastric feeding was received positively by patients and parents as a life-saving treatment when all other options to orally 'refeed' had been largely unsuccessful. However, patients reported that oral refeeding was preferable and encouraged other patients to 'try their hardest to eat' to avoid the 'traumatic' experience of nasogastric feeding. The study explored the importance of developing clear guidelines and considerations for nasogastric feeding, the importance of patient and parental involvement where possible, and the need to provide thorough education around nasogastric tube procedures to patients and parents.

One study reported on adherence of meal completion requiring patients in oral refeeding group to complete their meal under supervision by a trained nurse.[27] One study only required patients to eat enough food to restore their weight.[25] The remaining studies did not report on adherence to treatment.[24,26,28,29]

4 | DISCUSSION

The current review of seven studies found that for people hospitalised with an eating disorder there was low certainty evidence of no difference or a small increase in weekly weight gain with nasogastric refeeding compared to oral refeeding. There was little comparative information on the adverse events with the two methods of refeeding. No studies reported on the risk of refeeding syndrome, changes to electrolytes such as hypophosphatemia, hypokalaemia or hypomagnesemia, or changes to medical stability once nutrition support was commenced. To our knowledge, this is the first systematic literature review to synthesise comparative data between nasogastric and oral refeeding methods.

The finding of no difference or a small increase in weekly weight gain between refeeding methods questions the routine use of nasogastric feeding in some centres. Nasogastric refeeding has the potential for individuals with an eating disorder to increase their reliance on this method of feeding. Nasogastric refeeding also has the potential to mirror the dynamics in an individual with a past history of trauma or abuse, which can be psychologically unbeneficial.[9,10,32] It could be postulated that this type of refeeding method has the potential to also medicalise the illness and also promote negative behaviours around food. In one study, those who received overnight nasogastric feeding had a higher rate of relapse compared to those in the oral refeeding group on initial discharge from hospital, however, at 12-month follow-up there was no difference between groups.[24] While another study which compared oral refeeding and parenteral feeding to oral refeeding reported that the recovery rate was similar at 3-years post intervention between groups.[33] All five studies in the oral refeeding group met the overall aim for weight gain during hospitalisation of 0.5–1.0 kg per week with recent literature supporting refeeding at a higher rate during the first week of admission.[2] These findings suggest appropriate weight gain can be achieved with oral refeeding with the added benefit of normalising eating behaviours. However, although not identified in this review, it is possible there may be a subgroup of individuals with severe psychological illness who may still require nasogastric refeeding.[34]

In interpreting the results of this review, it appears that nasogastric refeeding was more likely to be prescribed in those patients who were more medically unstable. Those patients who received nasogastric feeding on

admission typically had a longer duration of illness (nasogastric refeeding weighted mean average 7.3 years, oral refeeding weighted mean average 7.2 years) and a lower baseline weight (nasogastric refeeding weighted mean average 36.8 kg; oral refeeding weighted mean average 37.6 kg) when refeeding was commenced. This potential selection bias makes it harder to compare the benefits and harms of the two refeeding approaches. However, one randomised control trial with a low risk of bias reported results consistent with the main findings.[24] The findings from this study showed that baseline weight and body mass index were similar between groups.

Despite the concerns of patients developing refeeding syndrome, there was little data reported on harms associated with refeeding hospitalised eating disorder patients. No studies reported on the rate of hypophosphatemia between nasogastric and oral refeeding groups. While this may be concerning, a previous systematic review reported on the minimal risk of hypophosphatemia with higher energy refeeding in conjunction with close medical monitoring with adolescents admitted to hospital with anorexia nervosa.[2] It is important to recognise that this systematic review[2] did not consider the increased risk of refeeding hypophosphatemia in severely ill adults with anorexia nervosa.[35] Further research is required to assess whether there is difference between refeeding methods and their risk of medical complications in severe and enduring adolescents and adults with anorexia nervosa. Additionally, it is important to consider that the total amount of weight gain was higher in the nasogastric refeeding group compared to the oral refeeding group and whether this has any psychological impact on the individual being treated. While it is important to acknowledge the purpose of hospital admission is to promote medical stabilisation, patients may demonstrate an inability to maintain adequate intake and weight gain once the nasogastric tube is removed, which can often increase the rate of relapse on discharge.[24,36]

To our knowledge, our systematic review is the first to investigate the effects of refeeding methods on the quality of care provided to hospitalised patients with an eating disorder. A strength of this review is that it adhered to the PRISMA guidelines, which is the recognised standard for reporting evidence in systematic reviews and meta-analyses. The search strategy applied was comprehensive and the methods of the study selection and inclusion criteria were determined before commencement of the review. The review did not restrict to English language which reduced the chance for publication bias.

There were some limitations. Most studies had a relatively small sample sizes which increases the possibility of bias. Most studies reported on females with anorexia nervosa, with one study reporting on adolescent males.[28] Although anorexia nervosa is a predominantly diagnosed in females the results of our review cannot be generalised to males with the condition. Similarly, the majority of studies included were non-randomised studies of interventions and therefore are more subject to bias, particularly selection bias. Future research should focus on evaluating refeeding methods with randomised control trials to reduce bias, although there may be ethical concerns in random allocation for a vulnerable population.

In conclusion, this review of seven studies provides information on the relative effects of nasogastric and oral refeeding methods on individuals hospitalised with anorexia nervosa. There was little or no difference in weekly weight gain with nasogastric refeeding compared with oral refeeding suggesting the benefits of normalising eating behaviour should be considered when choosing the refeeding method. However, those patients selected for nasogastric refeeding appear to be sicker with lower admission weight suggesting there may be a group of patients who require nasogastric feeding.

AUTHOR CONTRIBUTIONS

CB and NT designed and conducted the review; CB completed database searching; CB and NT completed article selection, risk of bias assessment, data extraction and data synthesis. CB and NT wrote and revised the paper and have read and approved the final manuscript.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bendall C, Taylor NF. The effect of oral refeeding compared with nasogastric refeeding on the quality of care for patients hospitalised with an eating disorder: A systematic review. *Nutrition & Dietetics*. 2023;80(1):44-54. doi:10.1111/1747-0080.12770

Received: 21 June 2022 | Revised: 14 September 2022 | Accepted: 28 September 2022

DOI: 10.1111/1747-0080.12784

Nutrition & Dietetics Journal of Dietitians Australia WILEY

REVIEW

Examination of the nutritional intake of patients undergoing opioid replacement therapy: A systematic review

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Funding information
Open access publishing facilitated by University of Canberra, as part of the Wiley - University of Canberra agreement via the Council of Australian University Librarians.

Abstract

Aim: This systematic review aimed to determine the level of existing research that investigates the intake, specifically macro and micronutrient intake, of patients undergoing opioid replacement therapy.

Methods: A systematic review was conducted across PubMed, Embase, Cochrane and CINAHL databases using a pre-determined protocol. Studies published between 2001 and 2022 assessing macronutrient or micronutrient intake in opioid replacement therapy patients were included. The Strengthening the Reporting of Observational Studies in Epidemiology checklist was utilised for quality appraisal. Data from each of the included papers was synthesised in a narrative manner. Data extracted included all measurements of nutrition including macronutrient, and micronutrient intake and any bioanalysis results and methods utilised.

Results: Seven papers (one cohort study and six cross-sectional studies, n = 443) were included that investigated an aspect of nutritional intake in patients receiving opioid replacement therapy. The majority of included papers reported an assessment of both macro and micronutrient and resulting energy intake as determined by food consumption. The included papers described a picture of irregular nutritional intake in patients undergoing opioid replacement therapy.

Conclusion: Minimal research into the nutritional intake of opioid replacement therapy patients exists. The existing research is suggestive of irregular nutritional intake from both macro and micronutrient consumption and indicates a need for further studies and increased attention on this vulnerable patient group.

KEYWORDS
dietary intake, nutrition, opioid replacement therapy, recovery, systematic review

1 | INTRODUCTION

Opioid use disorder is a recognised international public health issue affecting several countries globally.[1,2] There are an estimated 15.6 million opioid dependent people worldwide and the international consumption of opioids is believed to be increasing.[3] In Australia, each day approximately 150 hospitalisations involve opioid harm and three people die from drug-induced deaths involving opioid use.[1] In the United States, between 2000 and 2014, approximately half a million people died from a drug overdose, with opioids accounting for 61% of all drug-related overdoses in 2014.[2] In Australia, the overall rate of codeine-related deaths increased from 3.5 per million in 2000 to 8.7 per million in 2009 with deaths attributed to accidental overdoses found to be more common (48.8%) than intentional deaths (34.7%).[4] The opioid crisis has also affected Canada, who attributed 2861 deaths to opioids in 2016 with an average of 16 Canadians hospitalised each day due to opioid-related poisonings in 2016.[5] In Europe, especially the United Kingdom, there has also been an upward trend in the prescription of opioids and related mortality in recent years.[6]

Poor nutritional health among opioid addicted individuals is well established and a number of studies exist that demonstrate an increased likelihood of severe nutritional deficiencies in this population.[7] Patients with opioid use disorders have been observed to lack nutritional knowledge which leads to unhealthy eating behaviours.[7] Opioid addicted individuals have been shown to have a higher predisposition to the consumption of sweet foods and to consume less than the minimum amount of vegetable, fruit and grains recommended by relevant guidelines.[8,9] Several studies have demonstrated that the consumption of vegetables and fruit in opioid addicted individuals is less than the general population and that these individuals are prone to consume food with low vitamin content.[7,8]

Patients with opioid use disorders have also been shown to suffer from weight loss and irregular changes in dietary patterns.[7] When actively using opioids, individuals report little interest in food, preferring quick and cheap convenience foods.[10] Conversely, when abstaining from opioid use, there is evidence of binge eating disorders.[11] A predisposition to unhealthy eating behaviours in these individuals has been demonstrated and has been shown to be related to a lack of nutritional knowledge and food preparation skills relative to the general population.[7,12] Although the role of nutrition in detoxification has not been well defined, reports have suggested that an improvement in the nutrition of individuals with opioid use disorders may assist in the recovery process.[7,8,13]

Corresponding with the rise of opioid use disorders, there has been a subsequent increase in the number of individuals seeking treatment for this condition. The number of individuals being treated for opioid addiction has increased since 1990.[3] To combat the opioid addiction crisis, the use of legal opioid agonists, provided at regular dosing intervals to reduce withdrawal, has been implemented as a form of opioid replacement therapy.[14,15] Opioid replacement therapy has been shown to effectively treat opioid addiction.[14,15] Regular treatment is able to be adjusted to a dose that maintains blood levels of opioid agonists to suitably manage cravings and withdrawal without any associated intoxication.[3] A stable dose of opioid replacement therapy has been shown to lead to health and social benefits for patients, including reducing illicit drug use, criminality and improving both physical and mental health.[3]

The use of opioid replacement therapy is well established as a method to improve patients' mental health and reduce substance use, criminal activity and also mortality.[3] Several international studies exist that have investigated the nutrition-related intake of opioid replacement therapy patients.[16-19] It has been demonstrated that patients who participate in opioid replacement therapy have more favourable outcomes when coupled with appropriate nutritional intake.[7] Overall, however, there appears to be a paucity of research investigating actual nutritional intake rather than investigating nutritional health status through biometrics in this patient group.

Consequently, the aim of this systematic review was to determine the level of existing research that investigates the intake, specifically macro and micronutrient intake, of opioid replacement therapy patients.

2 | METHODS

A systematic review was conducted using a predetermined protocol based on the Cochrane Handbook for Systematic Reviews of Interventions.[20] This review adheres to the PRISMA guidelines.[21] This study is registered with PROSPERO (CRD4202127742). In terms of inclusion criteria, the primary outcome measures of interest of included papers were the following:

The nutritional intake of patients undergoing opioid replacement therapy in a community pharmacy or other government, or non-community pharmacy setting was evaluated through direct assessment of intake or bioanalysis of nutrient levels.

Search terms were formulated using the *PICO* structure. *Participants* (P) included patients undergoing opioid replacement therapy in a community pharmacy or other government, or non-community pharmacy setting. *Intervention* (I) included any assessment of nutritional intake such as via a food frequency questionnaire or food recall type assessment. *Comparisons* (C) included addressed intake intervention versus none in the opioid replacement therapy population, or in a non-opioid replacement therapy population. *Outcomes* (O) included any measurement of macro or micronutrient intake or levels. Papers were excluded is they evaluated patient nutritional status or measured utilised methods that differed to the above such as through anthropometric modelling.

Four electronic databases were searched for articles published in English from January 2001 to February 2022. This timeframe was selected to produce papers that reference the most up-to-date nutritional guidelines for the relevant reference countries. The databases searched were PubMed, Embase, Cochrane and CINAHL and the searches were conducted in April 2022. No restriction on study design was implemented for included papers. An electronic search strategy was constructed to incorporate opioid replacement therapy patients and nutritional intake through implementation of the following search terms:

1. opioid
2. opiate
3. OR/1-2
4. replac*
5. substitute
6. maintenance
7. treat*
8. therapy
9. OR/4–8
10. 3 AND 9
11. methadone
12. buprenorphine
13. OR/10-12
14. diet
15. nutri*
16. intake
17. health
18. OR/14-17
19. 13 AND 18
20. Remove duplicates from 19

The search strategy was constructed through use of the Pubmed database. Search terms encompassed medical subject headings and title words. The search strategy was then implemented across the further databases.

Titles were first screened by one author before abstracts of the identified papers were assessed by two authors against the eligibility criteria. References of relevant papers were also manually examined to identify any additional relevant studies. After reaching agreement, all papers that were deemed potentially relevant based on abstract or title were retrieved in full text to allow further detail assessment against the inclusion criteria. A third reviewer was consulted in the case of disagreement. Full-text screening involved using EndNote and Covidence software to manage and retrieve full texts. Figure 1 offers a schematic representation of this process.

Data from each of the included papers was synthesised in a narrative manner. Data collected included all measurements of nutrition including macronutrient, and micronutrient intake and any bioanalysis results. Methods utilised for the collection of this data was also collected for each included paper. Papers were reviewed by the chief investigator who assessed the individual studies to produce a descriptive summary of characteristics and relevant results. The synthesis of both methods and collected nutritional intake data was tabulated to allow direct comparison. Similarities between included papers and subsequent results was assessed as was the relationships between the included studies.

To appraise the quality of included papers, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist for observational studies was utilised.[22] The STROBE checklist facilitates the appraisal of methodological quality of six items which are subdivided into 22 criteria. Implementation of the STROBE checklist and assessment of study quality was undertaken independently by two reviewers. A third reviewer was consulted in the case of disagreement.

3 | RESULTS

The electronic search process yielded 1142 potential journal articles for inclusion. Of these studies, 934 were excluded based on title screening and duplicate removal. A further 194 papers were retrieved, and abstracts were screened against the inclusion criteria. An additional four papers were identified through reference checking of screened articles. These papers were also assessed against the inclusion criteria. A total of 18 articles were retrieved as full text documents. Eleven were found to be ineligible for inclusion, as they did not satisfy the inclusion criteria of investigating the nutritional intake of patients

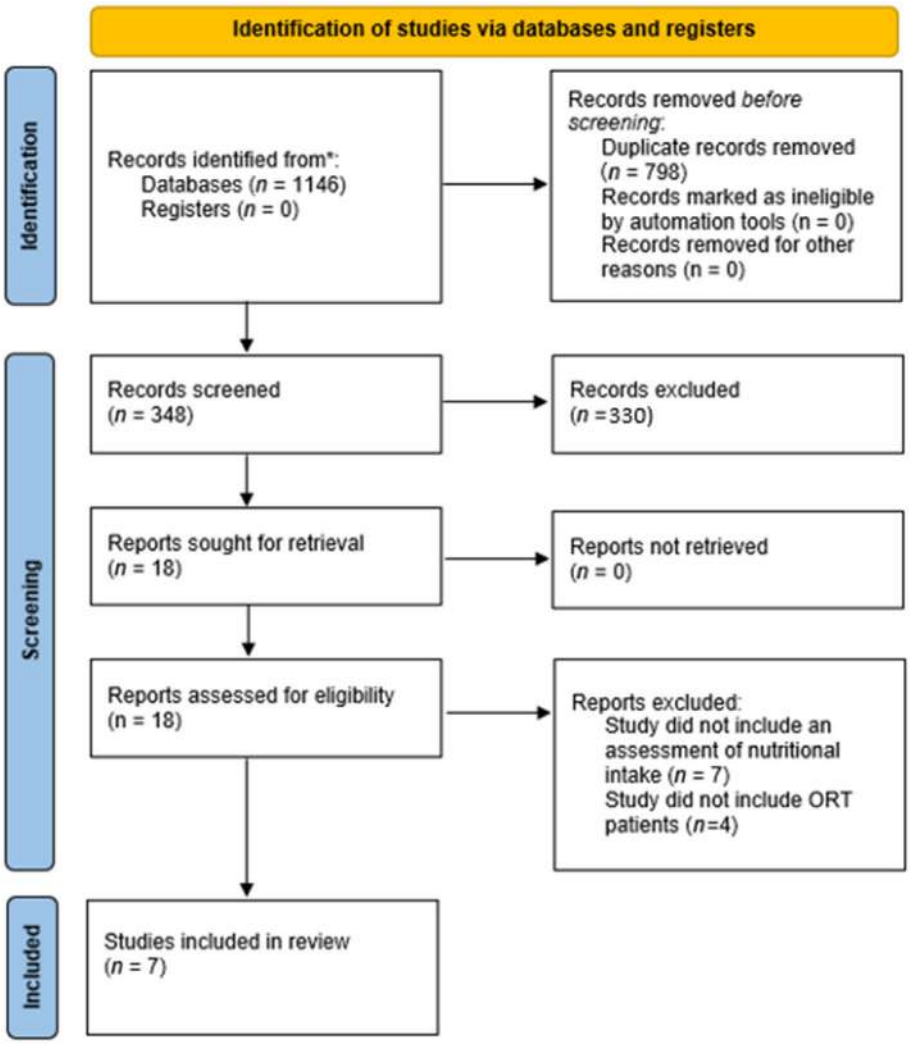

FIGURE 1 Study selection flow diagram

undergoing opioid replacement therapy, instead either investigating the nutritional intake of opioid addicted individuals or investigating nutritional knowledge of patients undergoing opioid replacement therapy. Seven studies were included for the final analysis.

Seven studies were included in this review (Table 1). Of these studies, two were conducted in the United States[26,28] and one study was conducted in each of Poland, the United Kingdom, Australia, Portugal and Iran.[9,23-25,27]

Each of the studies investigated an aspect of nutritional intake in opioid replacement therapy patients. Both Shrestha et al. and Tomedi et al. specifically investigated pregnant women.[26,28] Each of the remaining papers included both female and male participants. The largest patient sample size was investigated by Kheradmand and Kheradmand in their study of 198 individuals.[27] Tomedi et al. examined the smallest patient group of 22 patients.[26]

Patients receiving opioid replacement therapy treatment through various institutions were examined in the included research. The papers by Ii et al. and Waddington et al. examined intake in opioid replacement therapy patients receiving therapy through community pharmacies.[24,25] Tomedi et al., Alves et al. and Kolaryzk et al. included patients receiving therapy through single centres, a women's hospital, and a specialised Government department respectively.[9,23,26] Kheradmand and Kheradmand conducted their research across multiple opioid replacement therapy-specific treatment clinics.[27] It was unclear where the patients included in the study by Shrestha *et al.* were receiving their treatment.

Three (Kolarzyk et al., Ii et al. and Waddington et al.) of the included studies utilised a 24-h food recall to assess nutritional intake of patients.[23-25] The food recall assessment by Kolarzyk *et al.* was completed once at baseline and again following 4 years of opioid replacement therapy.[23] Ii et al. repeated the food recall assessment after a 4-month period.[24] Tomedi et al., Alves et al., Shrestha et al. and Kheradmand and Kheradmand utilised food frequency questionnaires as a method of assessing intake with Tomedi et al. also utilising biomarkers to assess micronutrient and essential fatty acid levels.[9, 26-28]

The majority of included papers included an assessment of both macro and micronutrient and resulting

TABLE 1 Characteristics of studies investigating nutritional intake in opioid replacement therapy (ORT) patients

Study	Origin	Study design and methods	Population	Patient sample size	Nutritional aspect investigated[a]	Outcomes
Kolarzyk et al. 2005[23]	Poland	Cohort study utilising 24-h food recall at baseline and after 4 years of ORT	ORT patients	30	Macro and micronutrient intake	Intake of micronutrients and carbohydrates below recommended levels
Ii et al. 2016[24]	United Kingdom	Cross-sectional study utilising 24-h food recall	ORT patients	25	Macro and micronutrient intake	Intake of fibre, selenium and potassium were significantly lower than recommended levels
Waddington et al. 2015[25]	Australia	Cross-sectional study utilising a single 24-h food recall	ORT patients	66	Macro and micronutrient intake and supplement intake	Irregularity in macronutrient contribution to energy and intake micronutrients below recommended levels
Tomedi et al. 2012[26]	United States	Cross-sectional study utilising food frequency questionnaire and micronutrient and essential fatty acid biomarkers assessment in pregnant ORT patients	Pregnant ORT patients	22	Macro and micronutrient intake and nutritional biomarkers	Significantly higher energy intake and poor nutritional status compared to control group
Kheradmand and Kheradmand 2020[27]	Iran	Cross-sectional study utilising food frequency questionnaire	ORT patients	198	Food group servings	ORT patients had an increased consumption of simple carbohydrates and were deficient in healthy food intake
Alves et al. 2011[9]	Portugal	Cross-sectional study utilising food frequency questionnaire	ORT patients	49	Food group servings, macronutrients, fibre, calcium and iron	ORT patients did not consume the minimum recommended servings of fruits, vegetables and grains and had an increased consumption of sweets
Shrestha et al. 2018[28]	United States	Cross-sectional study utilising food frequency questionnaire	ORT patients	53	Macro and micronutrient intake	ORT patients had significantly higher mean energy intake. Patients also demonstrated intake of vitamin D, vitamin E, iron, and folate below the estimated average requirements

[a]Macronutrients include fat, proteins and carbohydrates. Micronutrients include all vitamin and mineral products.

energy intake as determined by food consumption.[23-26,28] Kheradmand and Kheramand did not provide an analysis of nutrient levels.[27] Shrestha et al. and Waddington et al. also assessed reported nutritional supplement intake in their included patient groups.[25,28]

The STROBE checklist was utilised to assess the quality of the seven included papers. Each of the included studies utilised an observational, quantitative design. All the included articles met the STROBE checklist criteria for providing a clear balanced title and abstract, and also background and rationale within the introduction. In addition, each of the included papers included clear objectives and a statement of aims.

In relation to study methods, in all cases, study design was adequately presented however details of recruitment dates were not defined in two (28%) of the seven papers.[9,27] Participant eligibility was described in each of the papers and on all occasions the included population appeared to have been recruited appropriately. It was unclear in 2 (28%) of the included articles whether the chosen methods for measuring outcomes were appropriate due to single administration or minimal repetition of the utilised tools.[25,27] Additionally, five (71%) of the included articles were found to either not account appropriately for confounders or bias in study design or analysis of this was unclear.[9, 24-27] Five (71%) of the papers did not contain analysis of the potential bias in data collection.[9, 24-27] Statistical methods were adequately described in all but one of the included papers.[23]

On review of the results of each of the included papers, participant data and descriptive data were found to be adequately described across all studies. Six (85%) of the included papers met the criteria for having complete outcome data.[9, 23, 25-28] All papers included a summary of key results and provided a discussion of the generalisability of their respective results. Two (28%) of the papers lacked proper discussion of limitations and potential sources of bias.[9,23] Finally, the source and role of funds was not available for two of the included papers.[23,27]

In addition to the above analysis, it is noted that, ethical consideration was not clearly recorded in 2 (28%) of the included papers and other sources of potential bias include the low sample size observed in some of the studies and the inability for researchers to blind participants to the goals of their research.

All the included papers were considered to have produced valuable research.

A theme arising from review of the included studies was that nutritional intake varied between sexes but also that neither sex generally met the recommended values. Kolaryzk et al. found that women were observed to have a consumption of macronutrients that resulted in energy intake above recommended values.[23] Waddington et al. observed potential deficiencies in micronutrients and irregularities in energy intake from macronutrients across the sexes.[25] The results from Ii et al. also showed that intake differed between male and female patients however both sexes were observed to have potentially deficient intake of selenium, potassium, and fibre.[24]

In addition, Waddington et al. found that women reported potential insufficient intake of several vitamins including vitamin A, vitamin E and thiamin. Conversely, male intake of vitamins appeared to be more in line with Australian Government dietary guidelines.[25] Both female and male patients were observed to be consuming a high level of sodium and females were observed to have a low intake of both calcium and iron.

An increased intake of saturated fats and of fatty acids was also observed in both of the studies by Waddington et al. and Ii et al. with the latter concluding that increased attention to nutritional outcomes in this patient group suggested.[24,25]

In terms of investigation food group intake, Kheradmand and Kheradmand observed that intake of foods considered to be healthier, such as complex carbohydrates, vegetables and fish was low, whereas consumption of sweets was comparatively high.[27] The authors concluded that further investigation into appropriate diet in long-term opioid replacement therapy patients was required. Similarly Alves et al. observed that the intake of opioid replacement therapy patients did not meet the recommended daily intakes of the number of servings of fruit, vegetables or grains as per the food pyramid.[9] Additionally, individuals' daily consumption of sweets was high, at an average of over five servings per day.[9]

In those included papers that utilised control group comparisons, Shrestha et al. found that mean energy intake was significantly higher in individuals undertaking opioid replacement therapy compared to controls.[28] Comparatively, Tomedi et al. observed that pregnant women undergoing opioid replacement therapy reported an energy intake that was significantly higher than the non-opioid replacement therapy women (control group), with the opioid replacement therapy patients consuming more energy from sweets.[26] Intake of micronutrients and polyunsaturated fatty acids did not differ between opioid replacement therapy patients and the control group.[26]

The authors across all included papers concluded that opioid replacement therapy patients appeared to have poor nutritional intake and that proactive provision of nutritional interventions may benefit this population.

4 | DISCUSSION

This systematic review was conducted to investigate the current evidence regarding the nutritional intake of

patients undergoing opioid replacement therapy. Seven papers were identified that examined intakes of opioid replacement therapy patients through various methods. In summary, the review found a small body of evidence suggesting the nutritional intakes of opioid replacement therapy patients are lacking in various micronutrients and that opioid replacement therapy patients have unbalanced intakes of macronutrients. Several biases were observed in the included papers and therefore the findings should be interpreted with caution.

Three different methods of assessing opioid replacement therapy patients' nutritional intake were observed in the included studies: measurement of biomarkers, food frequency questionnaires and 24-h food recall.

It is suggested that measurement of biomarkers of certain nutrients presents the most accurate indication of an opioid replacement therapy patient's nutritional status as both food frequency questionnaires and 24-h food recalls rely on memory and cognitive function for accuracy, which can be negatively impacted by opioid replacement therapy.[25,27] Further, both the recall and questionnaire may be subject to recall bias and underreporting which has been reported to occur at levels of up to 30% of 24-h food recalls performed.[25] In addition to the issues of reliance on memory, the utilisation of a food frequency questionnaire is limited in ability to provide a measurement of energy intake.[26]

The 24-h food recall method is an accurate tool for assessing nutritional intake with research supporting several repetitions of the recall are required to ensure accuracy.[30,31] Specifically, previous research has suggested that the use of three repetitions performed on varying days of the week is necessary to provide an accurate depiction of an individual's actual dietary intake.[30] Both Ii et al. and Kolarzyk et al. conducted multiple food recalls.[23,24] Kolarzyk et al. present results obtained from three recall sessions conducted over separate, non-consecutive days of the week.[23] Similarly, Ii et al. conducted five recalls over varying days of the week.[24] Ii et al. further increased the accuracy of the obtained data by repeating their methods after a 4-month period to account for any dietary changes.[24] Comparatively, Shrestha et al. and Waddington et al. only implemented a single 24-h recall to assess intake and therefore the results obtained may not provide an accurate representation of the intake of this population.[25,28] Collection of data over multiple days of the week to increase accuracy is likely to be more achievable in this population due to their tendency to receive opioid replacement therapy on a daily basis. It should be noted, however, that the availability of subcutaneously dosed buprenorphine therapy may alter the ability to collect such data.

There is a lack of control data across the majority of included papers. Only Tomedi et al. and Shrestha et al. utilised a control group to provide a comparison of nutritional intake, with the other included papers comparing the intake of opioid replacement therapy patients to national recommended values.[26,28] It is therefore possible that the results of the five included papers without control groups in this review are indicative of nutritional intake issues that are not specific to the opioid replacement therapy population and may be representative of broader populational issues.

Most of the included papers provided a cross-sectional view of opioid replacement therapy patient nutritional intake. It is therefore unclear if the reported nutritional issues are due to opioid replacement therapy or if they existed in this patient group prior to therapy and may be attributable to other demographic factors. Research has illustrated that similar nutritional issues may exist in the general population and are contributed to by such factors as income level, education and race and therefore may not be specific to this patient group.[32] Consequently, future research directly comparing the nutritional intake of a non-opioid replacement therapy population with opioid replacement therapy patients may be necessary. Kolarzyk et al. examined patient nutritional intakes prior to opioid replacement therapy and then followed participants up 4 years after commencing opioid replacement therapy treatment and observed an improvement in nutritional intake.[23]

Nutritive intake plays an important role in recovery and maintenance of optimal health. Poor nutritive intake has been shown to lead to barriers to ceasing opioid consumption and good nutritional education may assist opioid withdrawal.[7] The outcomes of the included papers in this systematic review present a depiction of a population that is at risk of several nutritional deficiencies which subsequently may be playing a negative role in these patients' recovery and withdrawal processes.

In terms of macronutrients, a higher fat intake was observed in the research undertaken by Kolarzyk et al. and Ii et al.[23,24] Both Kolarzyk et al. and Waddington et al. observed higher intakes of proteins than recommended values.[23,25] Tomedi et al., Alves et al. and Kheradmand and Kheradmand noted an increased consumption of sweets, likely consisting of high levels of fats and sugars (carbohydrates).[9, 26, 27] An increased consumption of sweet products is commonly recognised in opioid dependant individuals.[10] Further research into the underlying mechanism for this preference is warranted.

As a result of this irregular consumption, energy gained from macronutrient intake appeared abnormal in the outcomes of Alves et al., Waddington et al., Shrestha et al., Kolarzyk et al., and Tomedi et al. (obtained via

food frequency questionnaire).[9,23,25,26,28] Energy intake was observed to be low in the study by Waddington et al., however, was found to be high in the papers by Shrestha et al., Kolarzyk et al. and Tomedi et al.[23,25,26,28] Appropriate energy intake is important for ongoing functions of cell metabolism and muscle performance.[33] Low energy intake may impair ongoing bodily functions and high energy intake may contribute to overweight and other associated comorbidities.[33]

A wide range of potential micronutrient intake deficiencies were observed across the included research. However, it is not clear from the available research if specific nutrient deficiencies are occurring regularly across this population. Rather, the research has shown that there appears to be a selection of nutritional issues occurring in these individuals. In terms of specific micronutrients issues that were observed across multiple studies, of note, low iron was observed in female participants in the results of Shrestha et al., Kolarzyk et al., Waddington et al., Tomedi et al. and Ii et al.[23-26,28] Waddington et al. and Kolarzyk et al. identified issues with calcium intake.[23,25] Sodium intake was high in the studies by Waddington et al. and Ii et al.[24,25] Both Waddington et al. and Ii et al. observed low intakes of selenium and potassium in opioid replacement therapy patients.[24,25] Further research is necessary to understand whether these micronutrient issues are able to be specifically associated with opioid replacement therapy populations.

The above-mentioned irregularities in micronutrient consumption are likely to have implications for opioid replacement therapy patient health. Vitamins play an important role in energy production and immune function whilst minerals are necessary for growth, bone health and fluid balance. Opioid replacement therapy patients have been shown to be at greater risk of poor nutritional status and malnourishment.[34,35] Poor nutritional status as a result of irregular intake of micronutrients can place individuals at risk of a range of comorbidities including cardiovascular disease, respiratory disease, diabetes and cancers.[27]

Each of the papers identified that this population may be suffering potential nutrient deficiencies due to unbalanced food consumption. However, it is not clear from the available research if there is any one single nutrient deficiency occurring in this population. There exists a consensus that further research in this area is necessary and that increased attention to nutritional intake; provision of supplementation; and increased nutritional education and advice may be beneficial in improving health outcomes in this population.

Several factors may be affecting the ability to determine a consistent pattern of nutrient insufficiencies in opioid replacement therapy patients. Food consumption, food preferences and subsequent nutrient intake, is determined by many influences. Such determinants of food intake include internal factors (sensory features), personal-state factors (biological features, habits and experiences), cognitive factors (knowledge and skills), as well as sociocultural factors.[36] Gaining an understanding of how these factors differ between opioid replacement therapy patients internationally is integral to understanding the full picture of nutritional health in these individuals. Further, understanding whether the nutritional health of opioid replacement therapy patients differs to the general population is also necessary. Future research in this area is necessary to understand the factors affecting opioid replacement therapy patient nutritional health and whether their nutrient intake differs from that of the general population. Further, utilising consistent methodology to research the intake of these individuals is necessary to understand which (if any) nutrients these individuals are at risk of lacking.

In terms of limitations, a more extensive review of the literature may be conducted through inclusion of non-English language papers and removal of a specific timeframe for publication of included papers. Due to the low number of papers that met the eligibility requirements, the included papers are not necessarily of a high methodological quality. Several included papers fail to account for external factors that may affect opioid replacement therapy patient's nutritional intake and do not provide a comparative patient group.

This systematic review found that there is currently little research investigating the nutritional intake of individuals undergoing opioid replacement therapy. The existing research paints a picture of poor nutrition-related health outcomes in this population and is suggestive of the need for increased intervention in this area.

Poor nutritional intake has implications for chronic comorbidities and may negatively impact ongoing patient health and addiction recovery. This review highlights the need for increased attention to nutritional intake and interventions in this vulnerable patient group.

AUTHOR CONTRIBUTIONS

FW and MN developed the initial research question and conceptualised the systematic review and methodology. FW, BW and VO contributed to literature searching, screening. data extraction and quality assessment. FW drafted the manuscript. MN and JT contributed to data interpretation and provided critical feedback on the manuscript.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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How to cite this article: Waddington F, Naunton M, Thomas J, Kyle G, Wheatley B, Oguoma V. Examination of the nutritional intake of patients undergoing opioid replacement therapy: A systematic review. *Nutrition & Dietetics*. 2023; 80(1):55-64. doi:10.1111/1747-0080.12784

Received: 13 February 2022 | Revised: 20 June 2022 | Accepted: 9 August 2022

DOI: 10.1111/1747-0080.12769

Nutrition & Dietetics Journal of Dietitians Australia WILEY

ORIGINAL RESEARCH

Gut health, the microbiome and dietary choices: An exploration of consumer perspectives

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Funding information
Open access publishing facilitated by University of Wollongong, as part of the Wiley - University of Wollongong agreement via the Council of Australian University Librarians.

Abstract

Aims: To explore consumer perceptions regarding dietary behaviours related to the gut microbiome, to assist in effective translation of research to practice.

Methods: Online focus groups were conducted (adults with no formal medical or nutrition training). Semi-structured open-ended questioning explored perspectives related to gut health and dietary behaviours. A qualitative descriptive analysis approach was undertaken in duplicate.

Results: Fourteen focus groups were conducted ($n = 38$, 15 males, 23 females). Four overarching themes regarding consumer perceptions were identified. These were (a) gut health equates with wellbeing, (b) there are divergent perceptions of how diet influences gut health, (c) interest in scientific evidence does not necessarily influence dietary behaviour and (d) gastrointestinal symptoms influence dietary behaviour.

Conclusions: Consumers are interested in gut health and understand that diet may be important. Given that current literature regarding diet and gut health does not differ from dietary guidelines, consumer interest may provide a timely slant to promote longstanding guidelines. Consumer education to limit scepticism around government messaging, including utilisation of social media by nutrition professionals, may be key to improving adherence to guidelines.

KEYWORDS

diet, dietary guidelines, gastrointestinal health, gut microbiome, qualitative research

1 | INTRODUCTION

The term 'gut health' is increasingly used in popular media and by the food industry to refer to the health of the gastrointestinal microbiome. Scientific literature suggests gut health incorporates digestive and immune health as well as microbiome health,[1–3] however the term remains undefined. Over the past 20 years, rapid advancement of microbiome sequencing has progressed the understanding of the role of gut microbes, the health outcomes they influence and ways to modulate these.[3–5] Commercialisation of gut health products appears to have capitalised on this growth market, sometimes outside of the evidence base.[1,6] Positions on optimal

microbiome characteristics and specific recommendations to achieve these remain unclear. Consumers' perceptions regarding gut health, including the microbiome, may be a useful start to inform science translation and health messaging.

From a science perspective, the composition, diversity and metabolite production of the microbiota is associated with a myriad of health outcomes including metabolic syndrome, mental health and autoimmune disorders,[7–10] hence there is plenty to be gained in translation. Diet is a significant modifiable factor in shaping microbiome characteristics and potentially associated health outcomes.[11] Despite this, evidence regarding precisely how diet influences microbes and associated health outcomes, is not yet at a level where confident prescriptions can be made. It is, however, accepted that a diverse, fibre-rich diet, as recommended in the Australian Dietary Guidelines,[12] has beneficial effects on metabolic health[13–16] and these are, at least in part, mediated by the microbiome.[17,18] While this broadly reinforces the need for promotion of these guidelines, researching the relationship between diet, the microbiome, and potential health outcomes remains problematic. Challenges include disparities in study design and the individualised and multifactorial nature of gut health.[19,20] The inferred need for consistent and comprehensive clinical trials providing the required evidence for dietary recommendations specific to gut health and associated effects is echoed in multiple reviews.[21–23] Understanding whether consumers are aware of these limitations may also assist in providing direction for better gut health communications.

The popularisation of 'gut health' has promoted certain dietary choices despite limited science.[6,24] While translational outcomes may be bettered with improved gut microbiome research design,[23] consumer needs should be considered at all stages. Given there is already heightened consumer interest toward 'gut health', the aim of this study was to explore consumers' perceptions regarding dietary behaviours related to the gut microbiome, to assist in effective translation of research to practice. This may inform science communication to guide appropriate health behaviours which can take advantage of the growing body of research on gut health related to the microbiome.

2 | METHODS

A qualitative descriptive approach was employed as we wished to explore the phenomena of gut health through the eyes of the consumer. Qualitative descriptive studies enable exploration of novel areas through detailed description of topics without an existing theoretical perspective.[25] Focus groups were chosen to enable interaction between participants, which supported wide-ranging discussion and encouraged exploration of diverse perspectives. Ethics was approved by University of Wollongong Ethics Committee, ETH2020/355. Participants (adults >18 years, without formal medical, microbiology, or nutrition training) were initially recruited using convenience sampling[26] through word of mouth and online social networks such as Facebook. Midway through recruitment, maximum variation sampling techniques[27,28] were employed to target underrepresented demographic groups. Specifically, males and adults aged >30 years were purposively recruited to achieve a balanced cohort by gender and age. Focus group transcripts were reviewed by a second researcher at two time points throughout data collection. Once both authors agreed that no new discussion points were emerging, recruitment was ceased. Information power was also considered in deciding when to cease recruitment with the study's broad aim, sparse specificity, cross-case analysis and lack of theoretical background considered.[29] Focus groups were conducted via Zoom (Zoom Video Communications, Inc Version 5, San Jose, California) between November 2020 and May 2021 and were led by one researcher to ensure consistency. Assistance was provided by an experienced qualitative researcher during initial sessions. Small focus groups were preferred based on the online format.[30] A written information and consent form was provided via email prior to involvement. No participation incentives were offered. Demographic information was collected via an anonymous online questionnaire (Appendix S1).

Focus group questions used an open ended, semi-structured style (Appendix S2). Study aims guided question development with a focus on exploring requirements for translational science in this area. Questions were developed, pilot tested and finalised collaboratively by all authors. Given the context of this study during the COVID-19 pandemic, questions initially queried perspectives regarding immunity, dietary choices and gut health. As early groups indicated consumers did not consider this relevant, these questions were not pursued further.

Focus groups were audio recorded, and with initial transcription using *Otter ai* software (Version 1.0, Otter.ai, Los Altos, California). To ensure verbatim transcription, one author listened and re-read all transcripts to ensure accuracy with a selection verified by another author. Transcripts were imported into NVivo qualitative data analysis software (Version 10, QSR International Pty Ltd., 2012). Transcripts were then read and re-read by two researchers to further immerse in the data. Data was independently reviewed and coded by both researchers using thematic analysis[31] to improve study rigour via

TABLE 1 Characteristics of the sample: consumers[a] ($n = 38$)

Demographic	*N*	%	Demographic	*N*	%
Gender			Area of residence		
Male	15	39%	Rural	7	18%
Female	23	61%	Suburban	20	53%
			Urban	11	29%
Age (years)			Income		
18–25	7	18%	<$50 000	6	16%
26–35	17	45%	$50 000–$79 999	14	37%
36–45	2	5%	$80 000–$119 999	10	26%
46–55	5	13%	$120 000–$150 000	2	5%
56–65	6	16%	>$150 000	2	5%
>65	1	3%	Prefer not to say	4	11%
Employment status			Education		
Full time	29	76%	Completed high school	6	16%
Part time	3	8%	Certificate/diploma	7	18%
Casual	2	5%	Bachelor's degree	18	47%
Student	2	5%	Master's degree	6	16%
Retired	2	5%	PhD/doctorate	1	3%

[a]Thirty-eight consumers were recruited to focus groups investigating consumer perceptions toward gut health. Inclusion criteria were adults >18 years, without formal medical, microbiology, nutrition training, no further exclusion criteria.

triangulation[32] and ensure intercoder reliability.[33] Codes were discussed and clustered with emergent themes identified inductively. Divergent views were considered in theme generation and are discussed. A second round of coding was completed to ensure all data was assigned to a theme with further discussion to finalise themes and sub-themes. Exemplar quotes were identified by both researchers and included quotes were chosen by consensus to ensure the best representation of findings.

A second stage of analysis was conducted using content analysis[34] to specifically focus on consumers perceptions of dietary choices that influence gut health. This flexible analysis approach is common in qualitative descriptive research to enhance depth of understanding.[25] Consumer perspectives were grouped and included based on frequency of mention. This was conducted independently by two researchers with outcomes discussed.

Purposeful approaches to ensuring research quality were employed.[35] One researcher was an experienced qualitative researcher and the second was a clinician/postgraduate research student. Both researchers were Accredited Practising Dietitians with knowledge of gut health research and an interest in translation of research to practice in this area. A reflexive journal was kept during focus groups documenting initial observations and emerging themes.[34] These were discussed between authors undertaking analysis to ensure ongoing reflection on personal contexts and influences on research processes and outcomes.[34,36] An experienced qualitative researcher not involved in the analysis provided feedback on question development and analysis outcomes.[35,37]

3 | RESULTS

Fourteen focus groups were conducted with 2–4 participants in each (n = 38). The two 2-person groups occurred due to last-minute scheduling issues. Each group ran for 45–60 min. The study sample included 23 females (61%) with 68% aged <45 years and 66% having completed higher education (Table 1). Four participants reported having Irritable Bowel Syndrome, no other conditions were disclosed.

Four overarching themes regarding consumer perceptions were identified, (a) gut health equates with well-being, (b) there are divergent perceptions of how diet influences gut health, (c) interest in scientific evidence does not necessarily influence dietary behaviour and (d) gastrointestinal symptoms influence dietary behaviour. A number of sub-themes were also identified within each theme (Figure 1 and Table 2).

Consumers equated the term 'gut health' with 'well-being' and overall health, associating gut health with mental health, cognition, immune and bowel health.

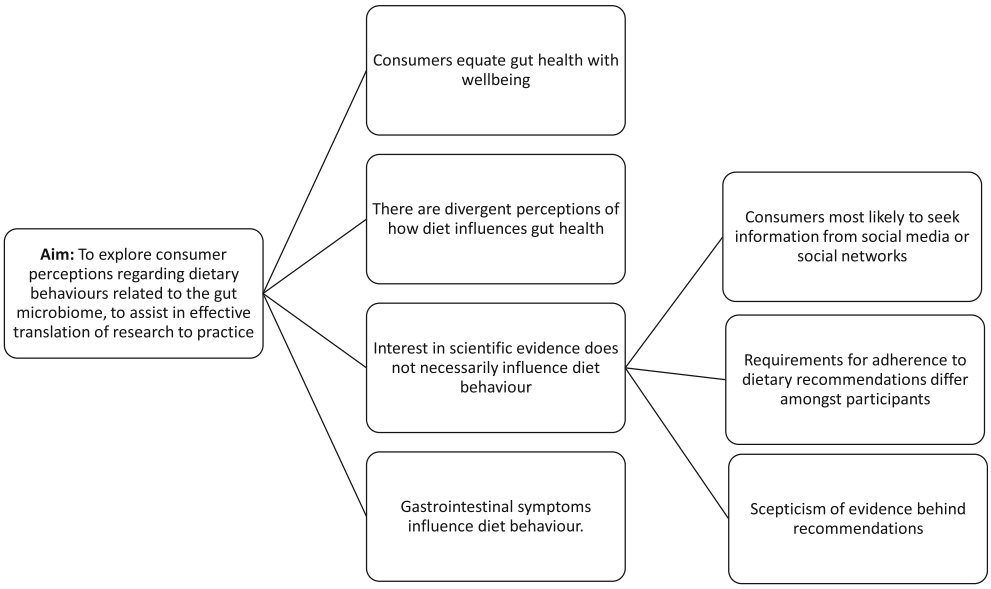

FIGURE 1 Thematic analysis outcomes of focus groups investigating consumer perspectives[a] of gut health and associated influences. [a] Thirty-eight consumers were recruited to focus groups investigating consumer perceptions toward gut health. Inclusion criteria were adults >18 years, without formal medical, microbiology, nutrition training, no further exclusion criteria.

Consumers generally evaluated their 'gut health' based on gastrointestinal symptoms such as abdominal pain and bowel regularity; however, noted broad influences on this such as sleep, mental health, physical activity and stress. For example, participants reported less gastrointestinal symptoms with lower levels of stress and associated this with 'good gut health'. The direction of this relationship, namely whether reduced stress improved 'gut health' or vice versa was unclear to participants.

All participants were aware of gastrointestinal bacteria, however, the extent of this knowledge was varied. Participants who had a greater understanding of the role of gastrointestinal bacteria reported an awareness of 'good versus bad' bacteria and a perceived importance of 'bacterial diversity'. These participants were more likely to associate broad health outcomes or 'wellbeing' with gastrointestinal bacteria while individuals who had limited knowledge beyond the existence of gastrointestinal bacteria, reported not considering the role of these in 'gut health' including gastrointestinal function. Despite this varied awareness and perceived importance, understanding of the function and health implications of gut bacteria was limited across most of the consumer group with few participants aware of the role of bacteria in maintaining the gastrointestinal environment and digestive processes.

The second theme identified that consumers have divergent views regarding how diet influences gut health. All consumers regarded diet as being the most influential modifiable factor on gut health. However, participants who reported awareness of the role of the gastrointestinal bacteria in health outcomes were more likely to attribute those health benefits to fermented foods or probiotic supplements, rather than prebiotic-rich foods recommended by national dietary guidelines such as wholegrains, fruits and vegetables. Participants were generally unaware of gut health implications of prebiotic-rich foods as they reported observing less microbiome-specific claims about these foods. Instead, prebiotic-containing foods including fermentable carbohydrates were more commonly associated with causing gut symptoms and therefore considered detrimental to gut health. Dietary choices listed by consumers are presented in online supplementary materials (Table S1).

Alternatively, participants who reported a limited awareness of the relationship between health outcomes and gut bacteria, listed high-fibre foods such as cereals, vegetables and legumes as being beneficial to 'gut health' as these were associated with digestive functioning rather than microbiome-related outcomes. Foods considered beneficial or detrimental to gut health were explored further with probiotic or fermented foods most frequently associated with 'bettering' gut health, and discretionary foods (foods not considered necessary for health) associated with worsening gut health. Foods recommended in the Australian Dietary Guidelines[12] were less frequently mentioned (Table S1).

The next theme identified that interest in scientific evidence does not necessarily influence dietary behaviour. While most consumers reported an interest in the evidence surrounding gut health and dietary influences, this did not always determine health behaviours in this area. An example of this was demonstrated by the gut health information sources identified by those participants citing a desire to understand the evidence, however who turned to social media, social circles, podcasts, radio or books for information. Participants who had not actively sought information regarding this topic reported coming across this information in television, social and

TABLE 2 Perspectives of focus groups participants[a] regarding gut health, the microbiome and dietary influences

Themes	Sub-themes	Key examples
(a) Gut health equates with wellbeing		*P29: 'I'd say a healthy gut is one you don't notice'* *P28: 'I mean, if something is bad for your gut health shouldn't it just be bad for you full stop'*
(b) There are divergent perceptions of how diet influences gut health		*P38: 'I have a lot of fermented food such as plant-based kefir and sauerkraut and leafy greens. I know they break down well in your gut and help with diversity'* *P29: 'I wonder in terms of gut health, if everyone was following that triangle (Healthy Food Pyramid) would gut health even be an issue? Do we need a different way of separating food just to target gut health, or do we just need to promote that more and get people to follow that?*
(c) Interest in scientific evidence does not necessarily influence dietary behaviour	Consumers are most likely to seek information from social media or social networks	*P41: 'we probably get most of our advice through social circles.... In terms of guidelines, I am aware that there are ones around, but it doesn't seem to get to front of mind in terms of the decision making process'* *P33: 'I look everything up on the internet. Doctor Google's great, isn't it?'*
	Requirements for adherence to dietary recommendations differ amongst participants	*P32: 'I need it to come from professional. If I want information, I would seek a nutritionist or doctor. I'm not gonna take the word of an Instagram or youtuber or Wikipedia article'* *P33: 'I tend to read all those recommendations and think, yep, that's great. But I go what works for me, if everything's working fine and I feel good, I just run with that'*
	Scepticism of evidence behind recommendations	*P3: 'I do think that's the problem with a lot of the government stuff. It's so behind, like the way that we look at food and our health has changed a lot in the last 5 years, but I don't really feel like a lot of the government sources have updated to acknowledge those things'* *P38: 'I'm a bit sceptical about some of the stuff in government publications just because of some of the reading I've done. I feel the food producers are involved in some of the advice'* *P29: 'I think of gut health, and I think that's clever marketing, you've turned this, this fizzy drink into being healthy. Regardless of whether it's actually good for you or not gut health, gut health has strayed into the buzzword category'*
(d) Gastrointestinal symptoms influence dietary behaviour		*P23: 'I'm pretty confident that if I went to my doctor, they want to know, specifically what the problem is. And if I don't have a specific problem, then it sounds a bit ... self-absorbed, because, to me, it seems like it's fairly resource intensive'* *P13: 'I think I would have to be motivated by a problem to make me change. So, if research came out that said you'd have to definitely have this to solve the problem you've got. I would probably lean that way but if I didn't think I had a problem I probably wouldn't be swayed by advertising or research or something'*

Abbreviations: FSANZ, Food Standards Australia and New Zealand; IBS, irritable bowel syndrome.

[a]Thirty-eight consumers were recruited to focus groups investigating consumer perceptions toward gut health. Inclusion criteria were adults >18 years, without formal medical, microbiology, nutrition training, no further exclusion criteria.

print media advertisements, primarily for probiotic supplements, as well as food labels. These consumers still reported an interest in whether these claims are supported by scientific evidence however this was often driven by financial concerns such as not wanting to spend money on a product that would not work. Interestingly, despite reported interest in scientific evidence, some participants reported that regardless of this evidence, when making dietary choices they prefer to 'go with what they know' namely, personal experimentation and experiences.

A disconnect between interest in evidence bases and actual behaviours was again evident regarding interest in individuals making health claims in this area. Despite participants' reported reliance on internet or word-of-mouth sourced information, participants also reported considering the qualifications of individuals making claims in this area and actively seeking information regarding this. Doctors, dietitians, nutritionists, and general scientists were considered trustworthy sources however the role of a health professional in gut health was considered unclear.

Food label 'gut health' claims were another area in which a misalignment between evidence and behaviour was evident. Some participants reported label claims increased their likelihood of purchasing that product and increased their faith in a product's health benefits. This was especially evident with fermented or probiotic foods such as kombucha, kefir and Yakult. Others, however, saw product health claims as 'marketing' and a deterrent to purchasing. Few participants reported they would 'fact check' a label's health claim. Generally, health claims on labels were considered confusing and were noted to only be considered if health concerns were present.

The evidence-based Australian Dietary Guidelines,[12] and potential for specific gut health related guidelines within these, was discussed with participants in order to inform translational opportunities. While most consumers were interested in the Australian Dietary Guidelines,[12] and thought gut health-specific recommendations should be incorporated within the current guidelines, a divergent viewpoint was evident with some participants reporting scepticism as a barrier to following current and future national dietary guidelines. This was attributed to confusion related to mixed messaging, distrust in scientific reporting (including bias in research), and a perception that government advice is outdated and influenced by commercial interests. Interestingly, these consumers reported confidence and trust in recommendations regarding dietary fibre intake, despite acknowledging limited understanding of specific health benefits. Participants identified this as a message provided by parents or school curriculums, that is, bodies with no commercial interest.

Participants that did report a role for gut health-specific guidelines within national recommendations suggested modifications including the addition of fermented foods, reducing dairy and meat intake, and emphasising plant-based, diverse and 'whole food' diets. Concerns regarding the blanket approach of population-based guidelines given the individualised nature of gut health were noted, as well as concerns that highlighting one food group may displace others, reducing dietary balance. Participants suggested transparent references and an awareness that the recommending body was independent would improve their confidence in forthcoming recommendations. Consumers identified practical 'food based' guidelines improve adherence. Participants also indicated a desire to understand the physiological processes behind dietary recommendations.

The final theme identified that gastrointestinal symptoms influence dietary behaviour related to diet and 'gut health'. Consumers reported the likelihood of making changes related to gut health was driven by curative, rather than preventative, health outcomes. Generally, individuals reported an increased likelihood to adopt changes if they considered their gut to be 'unhealthy'. This was associated with limited awareness regarding the role of gut health in preventative health, such as influences on non-communicable disease risk, which is a focus of dietary guidelines.

Individuals expressed uncertainty as to how to evaluate their gut health, with most assuming this would be based on bowel patterns. When questioned regarding how gut bacteria specifically could be assessed, most participants were unsure, however suggestions included colonoscopies, stool samples, hydrogen breath tests, and faecal transplant procedures. Most participants associated these with gastrointestinal conditions such as coeliac disease and did not consider bacterial profiling to be relevant for asymptomatic healthy individuals. A broader understanding of the role of gut bacteria was identified by a small number of participants who suggested that assessing gut health would incorporate external factors such as anthropometric measures, dietary intake, stress, and exercise.

4 | DISCUSSION

This research aimed to explore consumer perceptions regarding dietary behaviours related to gut health in order to investigate what is required for effective evidence translation to enable behaviour change. While extensive research is available regarding mechanisms related to gut health, diet and health outcomes,[17,38,39] to the best of our knowledge, limited research has explored

consumer perceptions regarding this relationship. This research identified consumer interest in gut health and recognised areas of focus for translational science in this area. This may direct future research and ensure the translation of outcomes allows for effective adoption.

Recent research exploring Australian adults' awareness of gut health found 66% of participants were able to define the term 'gut flora'.[40] Likewise, participants in our research indicated awareness of gastrointestinal microbes however most were unable to describe specific health effects despite recognising relationships between the microbiome and overall health. The direction of this relationship as to whether the microbiome influences health outcomes or vice versa, was uncertain amongst consumers. This is perhaps unsurprising as while consumer awareness of the multifactorial nature of gut health aligns with current research interests, scientific evidence regarding these mechanisms remains unclear. Recent research highlighted the complexities of microbiome research with >1500 significant associations found between microbiome-related outcomes and host factors such as diet, medications and disease.[8] While the interplay of these factors remains uncertain to researchers, evidence translation to inform consumer advice is limited.

Despite an awareness of the multifactorial nature of gut health, consumers regarded diet as the primary modifiable influence on the microbiome with fermented and probiotic-rich foods most frequently noted as beneficial. Similarly, the aforementioned research amongst Australian adults found a large proportion of participants (76%) reported knowledge regarding the term 'probiotics'[40] while only a third were aware of the term 'prebiotics'. Prebiotics are understood to benefit host health with advantages including convenience, low cost, and familiarity given their availability within well-known whole foods[41–43] and therefore promotion of these is warranted.

Consumers considered prebiotic and fibre-rich foods such as fruits, vegetables and whole grains to be integral to a 'healthy' diet however this was not necessarily attributed to microbiome-mediated outcomes. Despite consumers' reported 'confidence' in dietary fibre recommendations, this is not evident in national dietary intake data which indicates less than 30% of Australian adults meet recommendations for fibre intake.[44] Dietary fibre is accepted to beneficially modulate the gut microbiome and improve host health.[18] Consumer interest in gut health may present an opportunity to link what consumers already know about fibre with a 'gut health' focus in order to promote high fibre and prebiotic-rich foods currently recommended in national dietary guidelines. This is important given the aforementioned limited consumer understanding of prebiotics, despite being an area with substantial translatable evidence.[42,45]

Our research identified that consumers obtain information pertaining to gut health from social media and social circles. This is an important consideration in order to guide focus areas for nutrition communication given consumers reported a preference for obtaining dietary advice from these platforms rather than government publications. While there are concerns regarding the spread of inaccuracies through online communication platforms, they have been identified to be useful for the dissemination of information in a timely, engaging, and cost-effective manner.[46] A consumer criticism of current recommendations was the notion that these are outdated. Given the last Australian Dietary Guidelines[12] were released in 2013, it is valid to consider that, particularly in an area such as gut health which has grown rapidly over the past decade, the rigorous effort required to produce a body of work such as the Australian Dietary Guidelines[12] may limit its ability to remain contemporaneous. In contrast, numerous sources on the internet, of differing levels of credibility, may provide recommendations in this area, with immediacy, prior to official health bodies.[24] Marcon et al[24] reviewed information regarding 'gut health' in popular press and found information published on these platforms often overhyped current understandings of the microbiome with limited communication or evaluation of the scientific evidence behind these declarations.[24] Our participants reported interest in understanding the reasoning behind health recommendations and requested practical advice for incorporating recommendations into habitual diets. This presents an opportunity for scientific researchers to utilise information sources identified in this research to engage with consumers and ensure evidence-based and balanced recommendations regarding gut microbiome science are accessible. Tools such as social media enable the use of engaging graphics, videos and discussion to provide diet-disease education, recipe ideas, and cooking tips in an easy-to-follow way. Additionally, the engagement of health professionals to provide these messages on these platforms has been considered effective in publicising trustworthy messages.[47] The ability of social media platforms to allow for the 'sharing' of information enables conversation amongst peers and increases visibility of health advice, potentially improving the dissemination of information.[47–49]

Consumers noted concerns with the commercialisation of food products and questioned the independence of health recommendations behind food labelling with mixed messages across food labels, advertising, and government platforms leading to confusion regarding food selection. The role of food industry has been a longstanding concern within the nutrition space, with a cautious balance between the need to involve industry in conversations

regarding population nutrition to affect food supply while remaining independent, to ensure recommendations solely benefit health.[50–52] Food Standards Australia and New Zealand has standards to regulate the use of health claims on food labels. Health claims must be supported by rigorous scientific literature[53] with the enforcement of these standards regulated by state and territory governments. In terms of gut health, Food Standards Australia and New Zealand allows general health claims on products containing prebiotics and probiotics; however, specific quantities and health effects are not identified.[53] Few consumers were aware of any regulation regarding food label claims. An increased awareness regarding these regulatory requirements may reduce confusion associated with choosing supermarket products. Additionally, further responsibility by food companies to ensure packaging claims are clear and provide practical advice for health benefits, for example, 'one serving (1/2 cup) of this product provides "x" required for "y"' may assist consumer choices. It is unlikely that effective change regarding consumer food choices will occur without industry engagement. It is likely that change to improve consumer trust in health recommendations, and relevant food reformulation, will require sustained and rigorous policy-based regulation and incentives between governments, health bodies and food industry alongside a transparent and unified focus on improving population health.[51,52]

Despite associating 'gut health' with 'overall health', consumers reported they would not seek gut health-related advice unless they had specific symptoms. This focus on curative rather than preventative health behaviours is recognised as a barrier to the implementation of health promotion strategies despite preventative approaches often being the focus of health professional practice and dietary guidelines.[54] Interestingly, our participants stated they valued evidence-based advice, yet listed a range of reasons and influences why they would 'do what works for them'. This is similar to health promotion research identifying the influence of consumers' motivations, knowledge, social circles, and environmental factors on engagement with health recommendations.[54] Given the economic and health benefits of preventative health measures when successfully adopted, understanding these influences on individual behavioural change is important when constructing recommendations. Methods such as individual empowerment, tailored communication strategies, mass media campaigns, and health policy have been identified as useful to instigate preventive health practices.[54] This highlights the value of investment in education at a population, health professional, and individual level regarding the potential benefits of broad healthy habits in order to improve gut health and subsequently overall health, beyond digestive symptoms.

The qualitative nature of this research allowed for an in-depth and explorative understanding of consumer perspectives. While efforts were taken to ensure cohort demographics were representative of the general population, overall numbers were small and most participants were young to middle-aged females with tertiary education, and this may have influenced the apparent familiarity with topic concepts evident in our findings. This may inhibit the applicability of research findings to the broader population and further research using recruitment methods targeted at mixed education levels, may be required. The use of online platforms for this research presents both advantages and disadvantages. Online platforms are increasingly used for qualitative research. Evaluation of these platforms has identified suitable capacity for rapport building between moderator and participants as well as being convenient and user friendly.[55] The online format of this research was beneficial in terms of geographical flexibility allowing for recruitment from a range of locations. While data generated from small online focus groups has been considered satisfactory,[30] our focus groups with <3 participants ($n = 2$ groups) may have been limited in terms of generation of group discussion and interaction between participants.[56] This potentially limited data generation given reduced opportunity for presentation of diverse views and ability for participants to build upon these. Additionally, given the use of social networking for recruitment, some participants were familiar with the moderator which may have influenced responses. Attempts to acknowledge this through researcher reflexivity were made.

This research identified that individuals recognise the health of their gut is important however broader education is required to assist in understanding potential health implications including the potential role of the gut microbiome and the multifactorial nature of diet, lifestyle choices, environmental factors, and mental health in shaping the microbiome. This understanding would aim to influence a more proactive approach to making choices to optimise gut health. An important takeaway of this research is the understanding that individuals are aware that a diet in line with current dietary recommendations, focussing on diverse whole foods, is important for overall health. Despite this, a common misconception noted is the attribution of specific health benefits, namely better gut health, to fermented or probiotic foods as opposed to those currently recommended in the national guidelines, indicating a greater need for a broader conceptual understanding of nutrition and food composition. Further education, potentially through the engagement of health professionals and health bodies with social and traditional media platforms, to encourage and explain the importance of these food groups in this area, in ways that are transparent,

practical and applicable, may increase intake in line with current recommendations. The perceived importance of gut health and its current 'trend' status may allow a useful and timely slant to encourage consumers to align their intake alongside current recommendations, which are currently poorly followed. This is important as current literature regarding diet and gut health, does not differ from longstanding nutrition recommendations and as such connecting new ideas about gut health to established guidelines may improve the sense of credibility in nutrition messages.

AUTHOR CONTRIBUTIONS

Conceptualization, EJB, GMW; methodology, EJB, LCT, GMW; interview moderation, GMW; formal analysis, GMW, EJB; writing—original draft preparation, GMW; writing—review and editing, GMW, EJB, LCT; supervision, EJB, LCT; project administration, GMW. All authors have read and agreed to the published version of the manuscript. All authors declare that the content has not been published elsewhere.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

Data is available upon request from the authors.

ETHICS STATEMENT

Ethics was approved by University of Wollongong's Ethics Committee, ETH2020/355.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Williams GM, Tapsell LC, Beck EJ. Gut health, the microbiome and dietary choices: An exploration of consumer perspectives. *Nutrition & Dietetics*. 2023;80(1):85-94. doi:10.1111/1747-0080.12769

Received: 14 August 2022 | Revised: 14 August 2022 | Accepted: 31 August 2022

DOI: 10.1111/1747-0080.12778

Nutrition & Dietetics Journal of Dietitians Australia WILEY

ORIGINAL RESEARCH

Dietitians' perspectives on the role of dietetics practice in 'gut health'

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Funding information
Open access publishing facilitated by University of Wollongong, as part of the Wiley - University of Wollongong agreement via the Council of Australian University Librarians.

Abstract

Aims: This study aimed to explore dietitians' perspectives on the evidence surrounding the relationship between diet and 'gut health' and the current and emerging role of dietetics practice in this area.

Methods: A qualitative descriptive methodology was used. Online semi-structured interviews were conducted with Australian dietitians, focused on the perspectives related to gut health management in dietetics practice. Inductive thematic analysis was employed, commencing with initial coding by two researchers, and further coding leading to development of emergent themes. Divergent data were discussed and considered in analysis.

Results: Fourteen interviews were conducted (2 males, 12 females). An overarching theme identified that current evidence is insufficient to direct dietetics practice change regarding gut health. Six subthemes on dietetics practice in 'gut health' emerged including (a) practice is multifaceted, (b) current practice aligns with dietary guidelines, (c) symptom management remains the primary concern, (d) evidence-based information is sought, (e) translational evidence is required for practice change and (f) there is a role for dietetics in gut health research and translation.

Conclusions: Dietitians do not appear confident in their practice regarding gut microbiome-related management and recognise there is currently limited translatable research to inform practice. Evidence to date suggests that recommendations for positive gut health do not differ substantially from Australian Dietary Guidelines. Dietitians will need additional education if further evidence emerges, however they demonstrated a strong commitment to evidence-based practice.

KEYWORDS

dietary guidelines, dietitian, gastrointestinal health, gut microbiome, qualitative

1 | INTRODUCTION

Increased interest in the 'gut' microbiome over the past two decades is evident across research outputs, food industry, general media and popular culture.[1] This interest has broadened understanding of health outcomes related to the gastrointestinal tract, beyond that of digestive processes. Gut microbiota are associated with a myriad of health outcomes including modulation of immune, cardiometabolic, digestive and mental health.[2,3] These outcomes are mediated by processes such as microbial amino acid and vitamin production, direct interactions with immune cells, and systemic effects of fermentation by-products such as short chain fatty acids which provide energy for epithelial cells and are associated with appetite regulation, anti-inflammatory processes, and gut-brain signalling.[4,5] The direction of these effects are dependent on bacterial composition and diversity, both of which are influenced by age, genetics, environment, and diet.[2] Heightened interest in the gut microbiome has inspired the notion of 'gut health' and the promotion of behaviours to 'optimise' these broad areas of health via modulation of the gut microbiome.

Despite this, a universal definition of 'gut health' remains elusive. Whilst an 'optimal' microbiome remains undefined, exact strategies to achieve this are also not yet accessible. Given the known influence of diet on the microbiome and potential health outcomes associated with this, there is potential for dietary recommendations which aim to modulate the microbiome and improve broader health outcomes. Whilst dietary intervention studies in this space are abundant, translatable outcomes such as dietary recommendations, have thus far been limited. This is largely due to the intra-individual nature of the gut microbiome with wide variation in baseline microbiota and dietary patterns,[6,7] inadequate dietary assessment, and inconsistent engagement of nutrition professionals in study design and analysis.[8–10] This heterogeneity of evidence has thus far meant concise practice guidelines, or national dietary recommendations pertaining to dietary choices to better gut health, remain obscure.

Despite this, a diverse diet, rich in dietary fibre, is generally considered to improve bacterial diversity and benefit health.[11] Mediterranean style diets, incorporating predominantly plant-based foods such as legumes, fruit, vegetables, unrefined grain foods, and mono-unsaturated fats have been associated with favourable microbial profiles.[12,13] Furthermore, dietary choices aligned with those recommended in national dietary guidelines, have been observed to improve microbial diversity and the production of beneficial metabolites such as short chain fatty acids.[14] Alternatively, 'Western-style' diets, low in dietary fibre and high in processed foods, saturated fats and refined sugars, are associated with microbiome profiles related to poorer health outcomes such as metabolic syndrome.[15,16]

These patterns regarding dietary choices with potential to benefit microbiome outcomes align with national dietary guidelines. The Australian Dietary Guidelines promote population-level evidence-based recommendations for dietary choices to promote health and reduce disease risk.[17] These guidelines are developed based on rigorous review of scientific evidence including published literature, nutrient reference values, food modelling of practical serve sizes, and consultation with field experts, interested industry and government groups.[17] These guidelines form the basis of nutrition and dietetics practice. Therefore, with sufficient translatable evidence, the inclusion of recommendations specific to microbiome-diet mediated health outcomes within these guidelines would be well placed for adoption and promotion by health professionals with potential benefits at an individual and population level.

Dietary modulation of the microbiome to elicit health outcomes is an exciting area for nutrition care and thus research and subsequent development of practice guidelines demand the involvement of professionals with expertise in this area, notably dietitians and nutritionists. Given the evidence-based nature of dietetics practice, it is essential to ensure available evidence is valid, reliable and translatable in order to direct practice, and the perspectives of these professionals are highly relevant. Therefore, the aim of this study was to explore dietitian perspectives on the evidence surrounding the relationship between diet and 'gut health', and the current and emerging role of dietetics practice in this area. This aim was focused on understanding what is required for enabling translational research outcomes which can be adopted in practice to ultimately benefit client health outcomes.

2 | METHODS

Ethics was approved by University of Wollongong Ethics Committee, ETH2020/355. A qualitative descriptive approach was used to enable an in-depth description of a novel research topic through the lens of nutrition professionals.[18,19] This method is relevant when exploring novel topics with no pre-existing frameworks for themes.[19] Individual interviews were chosen to facilitate a detailed discussion regarding dietitians' perspectives and experiences related to gut health and dietetics care.[20] Recruitment initially involved homogenous purposive sampling methods[21] as recruitment targeted individuals with formal dietetics training, practising anywhere in

Australia. The study was advertised via social media, word of mouth, and in the newsletter of the national professional body for dietitians (Dietitians Australia). Midway through recruitment, maximum variation sampling was employed to target underrepresented groups and enable a breadth of sampling across years of experience, gender, and area of practice.[21] No monetary incentive was offered. Participants were provided with written information, consent form, and demographic survey prior to involvement (Supplementary Material I). Online interviews were conducted (Zoom Video Communications Inc. Version 5, 2020) from April to June 2021 led by a single researcher for consistency. An experienced qualitative researcher observed initial interviews and provided feedback on interviewing methods. This researcher also reviewed transcripts at two time points during the study with subsequent discussion between both researchers to determine when no new discussion points were emerging. This discussion, as well as consideration of sample information power including the broad study aim, dense sample specificity, dialogue quality and cross case analysis determined when recruitment was ceased.[22]

Research questions were developed in an open-ended, semi-structured style (Supplementary Material II) focussing on 'gut health' and dietary influences, and the perceived role of, and barriers to, dietetics practice in this space. All authors were involved in question development, testing and refinement. Interviews were audio-recorded and transcribed verbatim with the assistance of Otter.ai software (2016) by the lead researcher. A selection of transcripts were checked for accuracy by a co-author, in a process of further immersing researchers in the data. Transcripts were then exported to NVivo qualitative data analysis software (QSR International Pty Ltd. Version 10, 2012). Two researchers read and reread all transcripts to ensure familiarisation with the data. During this process, a thematic analysis approach[23] was employed independently with both researchers recording initial codes and emergent themes inductively. Codes and theme generation were then discussed and finalised collaboratively between researchers to improve study rigour via researcher triangulation.[24] Divergent themes were discussed and considered in analysis. Brief descriptive statistics were used to report participant demographics. Quotes were selected by both researchers undertaking the analysis with input by an additional researcher to ensure best representation of findings.

Research reflexivity was considered to ensure credibility of findings.[24,25] Both researchers undertaking analysis were Accredited Practising Dietitians with an interest in gut health and dietetics practice. Another researcher with experience in qualitative research reviewed question development and analysis outcomes to assist with reflexivity. The researchers acknowledged their positionality as an insider in this research and so kept a reflexive journal throughout the interview progress.[26,27] This was discussed between authors undertaking the analysis and a co-author experienced in qualitative research to ensure ongoing reflection on the influence of personal context on research aims and outcomes.

3 | RESULTS

Fourteen interviews were completed, lasting 45–60 min each. The study population included 12 (86%) females with 71% aged 26–35 years, considered generally representative of the dietetics workforce (94.6% female, average age 34.9 years).[28–30] Half the cohort worked across multiple industries including private practice, public health, and research with 8 (58%) in their first 10 years of practice (Table 1).

An overarching theme and number of subthemes were identified based on study aims. This overarching theme identified that current evidence is insufficient to direct practice change. Six subthemes on dietetics practice in 'gut health' emerged including (a) practice is multifaceted, (b) current practice aligns with dietary guidelines, (c) symptom management remains the primary concern, (d) evidence-based information is sought, (e) translational evidence is required for practice change and (f) there is a role for dietetics in gut health research and translation (Figure 1). Exemplar quotes for each of theme are presented in Table 2.

Broadly, participants considered the evidence base related to specific dietary influences on gut microbiome-mediated health outcomes to be too limited to direct substantial practice change at present. Participants were aware of, and interested in, the notion of 'gut health' and considered this a broad and individualised concept, related to gastrointestinal function, the microbiome, and overall health.

Dietetics practice regarding 'gut health' was considered multifaceted with participants initially associating 'gut health' with gastrointestinal symptoms. These symptoms were noted to be individualised in onset, management and treatment. Participants reported 'microbiome health' was also a consideration of 'gut health' however often considered tangible understandings of this to be limited. Aspects of microbiome-related health considered to be important included the concept of 'good' and 'bad' bacteria and gut 'diversity' as well as the microbiome's role in digestion and vitamin production; however participants reported incomplete mechanistic understandings of these processes. Despite not necessarily understanding the 'how', participants were aware of the microbiome's

TABLE 1 Demographic information of dietitians[a] participating in qualitative interviews addressing gut health in dietetics practice ($n = 14$)

Demographic	*N*	Percentage (%)
Gender		
Male	2	14
Female	12	86
Age (years)		
26–35	10	71
36–45	1	7
46–55	2	14
56–65	1	7
Employment status		
Full time	9	64
Part time	3	21
Casual	2	14
Area of residence		
Rural	1	7
Suburban	7	50
Urban	6	43
Income		
<$49 999	4	29
$50 000–$79 999	3	21
$80 000–$119 999	4	29
$120 000–$149 999	0	0
>$150 000	2	14
Not disclose	1	7
Education		
Bachelor's degree	4	29
Master's degree	5	36
PhD/doctorate	5	36
Area of practice		
Private	5	36
Public	1	7
Food industry	1	7
Research	1	7
Public/Research	2	14
Private/Research	4	29
Private/Public	1	7
Years of practice		
<5	5	36
≥5 to <10	3	22
≥10 to <20	2	14
≥20	4	28

[a]Fourteen Australian dietitians were recruited for online interviews investigating perceptions towards gut health. Inclusion criteria were practising dietitians with formal nutrition and dietetics training, aged >18 years.

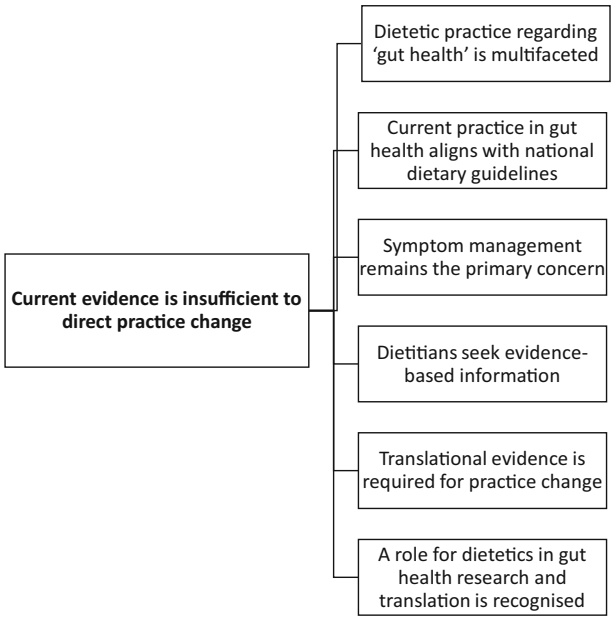

FIGURE 1 Gut health in dietetics practice—current perceptions as identified by dietitians participating in qualitative interviews addressing gut health in dietetics practice ($n = 14$)

influence on health effects beyond the gut alongside a perception that 'good' gut health is associated with overall health or 'wellbeing'. The multifactorial nature of gut health was further recognised with participants reporting management of 'gut health' required consideration of factors beyond diet including mental health, sleep and medical history. Dietitians reported emerging evidence to support this multifactorial approach however also noted anecdotally that these factors were rarely present in isolation, that is, poor dietary choices are often the result of, or contribute to, stress, poor mental health and lack of sleep and exercise. Some participants felt these factors fell outside their scope of practice however most felt confident addressing these factors or referring onwards as required.

Participants reported current practice regarding gut health aligns with national dietary guidelines. Participants reported sufficient evidence is available regarding the role of diet in broadly shaping 'gut health' inclusive of gastrointestinal symptoms and microbiome outcomes, however specific recommendations namely particular nutrients or dose requirements remain unclear. As such, an evidence-based 'food first' approach as recommended by the Australian Dietary Guidelines was considered the first step to improving gut health, with dietary fibre identified as the most beneficial component. Participants felt confident promoting foods recommended in the Australian Dietary Guidelines as beneficial for many reasons, including gut health, as this did not differ to usual practice.

TABLE 2 Perspectives of dietitians participating in online interviews[a] regarding gut health, the microbiome and dietary influences

	Subthemes	Key examples:
		Participant ID (years of experience, area of practice, residence)
Current evidence is insufficient to direct practice change	Dietetics practice regarding 'gut health' is multifaceted	D9: (>20 years, private/research, urban area) '*Gut health means you don't have to think about it, it's functioning in a way that is comfortable and isn't causing symptoms or negatively impacting quality of life*' D5: (10–20 years, private, suburban area) '*it's addressing emotional health, physical activity or sleep, you usually can find what is contributing to poor gut health through trialling a wholistic approach essentially*'
	Current practice in gut health aligns with national dietary guidelines	D13: (>20 years, industry, urban area) '*What constitutes a healthy diet I think also constitutes a healthy microbiome. The modern processed diet doesn't do us any favours*' D2: (5–10 years, research, urban area) '*I think despite what all the new research shows, we''re still going to end up with very similar guidelines to what we have now in that people just need to eat more fruit, vegetables, grains, nuts and seeds. It's just a different way to package that information*'
	Symptom management remains the primary concern	D7: (0–5 years, private, suburban) '*It wouldn't be a primary thing. I use it as a secondary strategy to motivate people by describing how changing the gut bacteria might influence other health conditions*'
	Dietitians seek evidence-based information	D10: (0–5 years, private, suburban) '*I don't come across information readily, I have to pick it out to find it. I do a search to find a journal article, then review it to make sure it's a good quality study*'
	Translational evidence is required for practice change	D12: (>20 years, private, suburban area) '*It's only been in the last few years that people are really starting to understand just how important ... potentially ... I will use that word... gut health is in terms of its effect it can have on other things. But the mechanisms I don't feel are fully understood to make me do anything differently yet*' D4: (5–10 years, private/research, urban area) '*I'm always upfront with clients, I often say this is what we know now, this could change, this needs more research, but this is what current research is suggesting*'
	A role for dietetics in gut health research and translation is recognised	D8: (10–20 years, private, suburban area) '*I think the gut microbiome is much more influential than we've ever thought about. I think as dietitians we haven't really considered bacteria as much as we should have. So, I feel like there's another whole aspect of dietetics that we know very little about that. I do believe that in terms of our diet therapeutics, that we should be focussing on that much more, particularly in in terms of mental health and obesity and all of the things that the microbiome is starting to be related to. And I also think we need better ways of describing that to our clients*'

[a]Fourteen Australian dietitians were recruited for online interviews investigating perceptions towards gut health. Inclusion criteria were practising dietitians with formal nutrition and dietetics training, aged >18 years.

Alternatively, participants were less confident with recommending 'new' products such as fermented foods and probiotics. Probiotic food sources such as yoghurt, sauerkraut and kefir were considered to potentially benefit health however given perceived inadequate evidence to support their use, participants reported recommendation of these was not part of standard care. Participants reported being cautious not to overstate the evidence regarding these foods and instead focus on transparent advice indicating these foods cannot be endorsed as evidence-based recommendations. An additional barrier to the recommendation of these foods was participants' focus on recommending familiar, practical and inexpensive food options, which limited recommendation of often costly and inaccessible gut health-marketed products such as fermented drinks.

Participants again aligned foods considered detrimental for gut health with foods discouraged in the Australian Dietary Guidelines such as discretionary and processed foods, refined sugar and alcohol. Additionally, caffeine and food additives including emulsifiers and artificial sweeteners were identified as potentially hindering gut health. Food behaviours were also noted to contribute to gut health with binge and emotional eating, cyclic

diet patterns and restrictive food choices perceived to be harmful.

Current dietetics practice was noted to consider microbiome outcomes secondary to tangible 'gut health' outcomes such as symptom management. Microbiome specific practice was rarely considered the principal or initial focus of care unless it appeared in a patient's identified goals, and it rarely altered practice with recommendations still focused on an individualised approach based on Australian Dietary Guidelines principles. Instead, participants reported management of gut health in both inpatient and outpatient settings generally centred on gastrointestinal conditions (e.g., irritable bowel syndrome, inflammatory bowel disease, coeliac disease or post-gastrointestinal surgery) or symptom management with a focus on individualised care. Participants reported that symptoms such as bloating and wind are part of normal functioning and did not necessarily imply poor gut health as often presumed by clients. However, these symptoms may imply poor health if causing distress or pain and as such 'gut health' was considered highly individualised given this threshold differs between persons. Additionally, management of this focused on individualised recommendations including consideration of food intolerances and preferences.

Participants highly valued scientific evidence as an information source. Participants reported a substantial increase in information regarding gut health and diet over the past decade, with many participants reporting this concept was not taught within university degrees and required independent study. Participants emphasised the importance of evidence-based research with information sought from journal articles, books, webinars, podcasts and nutrition practice databases. Social media outlets including Instagram, LinkedIn and Twitter were also utilised when content was produced by a health professional. Participants identified challenges with understanding and keeping abreast of the literature and this presented a barrier to confidence with 'gut health'-related practice.

Translational evidence was highlighted as essential for dietetics practice change however divergent perspectives on research quality and potential for translation were evident. Some participants considered current evidence to be of a high standard given the large number of randomised control trials. Others saw issues with dietary assessment methods and limited use of nutrition professionals as a barrier to translational outcomes. Most agreed that evidence supporting dietary manipulation to promote gut health is promising but not yet adequate to enable recommendations for practice, particularly given incomplete mechanistic understandings. Participants noted barriers for translation of evidence in this area to include the multifactorial and individualised nature of gut health, client health literacy and varied engagement with recommendations.

Participants recognised a role for dietetic involvement in gut health research and translation. Given the substantial influence of diet in shaping multiple facets of gastrointestinal health, participants felt they should remain engaged with the scientific literature and practice possibilities in this area, despite the lack of current translational evidence. An evidence-based practice guideline, particularly regarding probiotics, would be useful. Dietitians suggested that tangible outcomes related to gut health, such as microbiome compositional analysis may assist dietetics practice and consumer engagement and education. There was a need for advocacy for dietetics expertise in this area including highlighting the relationship between health outcomes, diet and the microbiome within the medical profession to stimulate referrals, and to improve the quality and relevance of research efforts. Participants noted increased client interest in 'gut health' specifically related to the gut microbiome and considered this motivation to remain informed in this area.

4 | DISCUSSION

This research aimed to explore dietitian perspectives on the evidence surrounding the relationship between diet and 'gut health' and the current and emerging role of dietetics practice, with a focus on identifying what is required to optimise practice in this area. All participants were Accredited Practising Dietitians and recognised a role for dietetics practice in gut health as a multifaceted term incorporating both gastrointestinal symptoms, microbiome outcomes and broader influences.

Dietitians Australia describes dietitians as evidence-based nutrition professionals specialising in individual dietary counselling whilst promoting health at a community and population level.[31] In the area of gut health, our research found Australian dietitians recognised and highly valued the importance of this individualised and evidence-based approach. Consistently, a barrier to progressing practice in this area, particularly regarding diet-microbiome mediated health outcomes, was the lack of translational scientific evidence in this area.

The importance of dietetics practice in gut health is underpinned by the acceptance that gastrointestinal health outcomes, including gastrointestinal symptoms and microbiome outcomes, are influenced by diet.[32–34] Dietitians in our study recognised their expertise in dietary management of gastrointestinal conditions and symptoms however the multifaceted and individualised nature of the microbiome, was identified as a barrier to

dietetics practice in this area. Whilst diet accounts for >20% of microbiome variation,[7] gastrointestinal function and microbiome outcomes are also influenced by environmental, genetic and behavioural factors.[16,35,36] Dietitians in our study recognised these influences and noted practice in this area would require wholistic, multidisciplinary and unique management for each person. This focus on multidisciplinary approaches to gut microbiome research and translation to practice is echoed across multiple reviews.[10,37] Therefore, moving forward, comprehensive management would require increased awareness, of dietitians as well as general practitioners, psychologists and exercise physiologists regarding the dynamic and interconnected nature of mental and physical health, and the effect on and of the gut microbiome.

The individualised nature of the gut microbiome aligns with the concept of 'personalised nutrition'. Multiple studies identify intra-individual responses to dietary interventions with potential for an array of dietary advice, from beneficial to redundant dependent on baseline microbiome characteristics.[38,39] Dietitians in our study were more confident managing symptom or disease-based 'gut health' because they had evidence-based guidelines for management.[40–44] In these specific medical conditions where symptoms provide a measure of improvement, dietitians recognised the value of their knowledge and skills. As such, research in diet–microbiome interactions should prioritise capacity for clinical translation including practice guidelines and measures of change, in order to enhance practitioner confidence in this area.

Notwithstanding, dietitians already have many skills that may be relevant in understanding the microbiome, as individualisation is a cornerstone of care.[31] This is evident in current gastrointestinal disease and intolerance management with therapeutic diets useful for some individuals can be detrimental to others. For example, elimination diets[45] applied in the treatment of irritable bowel syndrome require exclusion of foods considered 'healthy' for a general population group. This emphasises the expertise of dietitians in providing personalised dietary management to ensure nutritional adequacy, a skill which will likely be essential in future 'gut health' related practice.

Despite a myriad of intervention trials investigating food and nutrient effects on the microbiome, current hypotheses reflect dietary patterns rich in dietary fibre, polyphenols and unsaturated fats are likely beneficial for gut health.[13] This does not differ from what is currently recommended in national dietary guidelines. We found dietitians to be very clear in understanding that a diet for 'good gut health' would not differ to the Australian Dietary Guidelines recommendations. In contrast, our recent research investigating consumers perceptions on diet and gut health reflected a focus on probiotics and fermented foods to better gut health, with limited understanding of benefits of foods included in national dietary guidelines.[46] Dietitians noted increased consumer interest in 'gut health'. Given current poor adherence to the Australian Dietary Guidelines,[47] despite evidence-based benefits across many health areas, including microbiome outcomes, increased consumer interest in 'gut health' may present an opportunity for dietitians to promote these guidelines as a way to better 'gut health' whilst likely promoting broad positive health outcomes.

Dietitians reported diet-microbiome outcomes were rarely the principal focus of dietary interventions, in part due to limited definitions as to what defines 'gut health' and inadequate tangible outcomes to assess change. This again highlighted the emphases on adequate evidence being required for dietetics practice change. Attempts have been made to define 'gut health' however these are generally varied and incorporate multiple concepts including gastrointestinal symptoms and disease, immunity, microbiome characteristics[48] and overall well-being.[49] Without consistent dietary methodologies, robust analysis and good study design with a focus on translational capabilities, these ambiguities remain and likely will continue to limit practice progression in this area.

Despite identified challenges, dietitians in our study acknowledged a need for engagement in the gut microbiome space, driven by increased interest from clients as well as the positioning of food industry and social media personalities in this area. To date however, limited research has addressed clinical implications in this space. A study in Qatar also identified health professionals' interest towards microbiome targeted health care with the majority (95.5%) aware of dietary influence in this area, however 95% reported minimal understanding of the specificities regarding how health care could be used to target microbiome-related outcomes.[50]

Clearly translational research enabling evidence-based recommendations is required to enable meaningful practice. This requires nutrition expertise in study design involving nutrition intervention to ensure dietary data are captured accurately and interventions are reproducible and relevant.[10] Microbiome and diet research has focused both on single nutrient and whole food-based effects. Nutrient-focused research allows for specific mechanistic understandings as well as easier delivery and quantification. However, as humans generally consume foods in their whole form, outcomes evidenced in single nutrient studies may not be reproducible with whole food intake due to the dynamic nature of the food matrix.[9,51] Additionally, dietitians in our study noted a food first

approach was preferred in practice, addressing economic issues and convenience. As such, food-based interventions may be more useful in producing outcomes that can be implemented in practice. Dietitians can help plan standard study designs and advise on systematic review and meta-analysis research. This would help build mechanistic understanding and develop recommendations for practice. Given the time-consuming nature of evidence review, the development of concise general recommendations may clarify and support practice pertaining to gut health. Furthermore, based on our findings on information sources, dietitians encourage the dissemination of research findings via evidence-based platforms, webinars, podcasts and social media (all delivered by qualified professionals) to ensure broad circulation.

The use of online platforms in this research presents both benefits and limitations. Online platforms utilised for this research carry risks including technical difficulties, however have been evaluated as user friendly and capable of allowing for suitable rapport building[52] as well as allowing for increased recruitment across a broader geographical area.

This research found the current perceptions and practices of dietitians regarding diet- microbiome mediated health outcomes are evolving but there is a need for evidence-based guidelines to direct individualised and multidisciplinary management. The development of these guidelines would require a focus on improving the reliability and validity of current evidence and ensuring study design enables evidence translation. Until this is possible and whilst evidence suggests dietary choices to benefit the microbiome align with recommendations included in national dietary guidelines, increased consumer interest in gut health may offer dietitians an opportunistic reframing of these guidelines to improve adherence and overall nutritional health of populations.

AUTHOR CONTRIBUTIONS

Conceptualisation: EJB and GMW. *Methodology*: EJB, LCT and GMW. *Interview moderation*: GMW. *Formal analysis*: GMW and EJB. *Writing—original draft preparation*: GMW. Writing—review and editing: GMW, EJB and LCT. *Supervision*, EJB and LCT. *Project administration*: GMW. All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ETHICS STATEMENT

Ethics was approved by University of Wollongong Ethics Committee, ETH2020/355.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Williams GM, Tapsell LC, Beck EJ. Dietitians' perspectives on the role of dietetics practice in 'gut health'. *Nutrition & Dietetics*. 2023;80(1):95-103. doi:10.1111/1747-0080.12778