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Systematic reviews in nutrition and dietetics

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EDITORIAL

In a world dominated by the world wide web and social media, it has never been more important that nutrition and dietetics research is of high quality. For information to be accepted authoritatively, it is essential to have trust in the research process and research methods used. This applies across all users of research; the public, as well as researchers, practitioners, policy makers and funders. Furthermore, with the rise of predatory journals it is especially important that reputable journals uphold the highest standards of research integrity; methods employed in research are a key foundation of research quality. Improving the quality of research published in *Nutrition & Dietetics* has been a particular focus in recent years, and this is reflected in recent improvements in impact factor and other quality measures for the journal. The focus of this issue of the journal is on methodologies in nutrition and dietetics research and reflects the collaborative efforts of the profession in strengthening knowledge and its translation to improve nutrition outcomes for individuals, groups and communities. Special thanks must go to all authors that have contributed to this issue, many of whom also serve on the editorial board, and whose articles further assist *Nutrition & Dietetics* with its focus on publishing high-quality research.

There are many checklists and guides to ensure rigour and trustworthiness in research reporting. Some of these are referred to in this journal's instructions for authors. The article from Palermo and colleagues within this issue challenges researchers to go beyond the checklists in our pursuit of research quality. It describes the importance of internal coherence and defines the concepts that must align to achieve this coherence, including ontology, epistemology, axiology and methodology. It is a call to action for authors, peer reviewers and editors to work together to achieve internal coherence and improve the quality of published research.¹ The issue also includes a range of papers describing relatively new methods for nutrition research, along with new applications of better-known methods to further nutrition research.

Amongst the newer methods for nutrition and dietetics are those methods focused on the application of research to the practice setting including realist research and implementation science. Realist methods provide important contextual information on the evidence for complex interventions, and attempt to identify the mechanisms which make an intervention effective—essentially developing and testing a program theory for interventions. The paper in this issue by Jenkins et al describes

how realist methods for evaluation or synthesis have been used to date in nutrition and dietetics research. The authors found that realist methods have been restricted to public health nutrition interventions to date. Given the complexity of dietary interventions, realist methods have great potential in effectively translating evidence from nutrition and dietetics research into the practice setting. Researchers from across all domains of practice could embrace realist methods as a tool to navigate the complexity inherent in nutrition and dietetics research questions.²

Another theory-led approach to research—perhaps better known—is implementation science, which focuses on improving the uptake of evidence-based interventions in practice. Although translation of research into practice has been recognised as an area requiring attention for many years, it is only in recent times that nutrition and dietetics research has purposefully adopted an implementation science approach. In another paper in this issue, authored by Young and colleagues, the application of implementation science methods to nutrition and dietetics research is demonstrated using a multiple case study approach. The selected case studies provide guidance to those who may be new to implementation science, and provides points for reflection for those more experienced in use of implementation theories to address evidence-practice gaps.³

Nutrition research is constantly evolving, and researchers may easily overlook some of the newer methods being adopted to understand the relationship between diet and disease. The gold standard “randomised controlled trial” has proven difficult to justify in nutrition research given the impracticalities of the method for dietary intake studies, encompassing cost, time to outcome, and the inability to “blind” participants and researchers to what they are eating. The application of a study design developed for pharmacological trials to dietary behaviour research with all of its complexity has been criticised previously.⁴ This issue includes two papers that use methods to overcome these shortcomings. The paper by Zhou and colleagues uses a bidirectional Mendelian randomisation method to investigate associations between salt added to food and body mass index. The findings support a causal link between them.⁵ Mendelian randomisation allows researchers to determine causal relationships without conducting an intervention study, through genome-wide association data obtained from biobanks. The method avoids traditional limitations of observational studies, most significantly the issues of confounding and potential for reverse

causation.⁶ The interesting concept of outcome-related food scores is another method to reduce confounding in nutrition research and is illustrated in the article by Correa Leite, also in this issue. These scores are developed using statistical methods that allow foods to be ranked according to their potential impact on health outcomes, independent of the amount of the food consumed. The researchers use population data to illustrate selected food scores and their relationship to blood lipid levels and waist circumference, indicating small differences only between most individual foods and these outcomes.⁷ As these methods continue to develop and are used by nutrition researchers, we may begin to discover more efficient ways of conducting dietary research that overcome the challenges inherent when measuring dietary intake and drawing conclusions about longer term health outcomes.

Also featured in this issue are existing methods and their application to current issues relevant to nutrition and dietetics. In a scoping review by Bennett and colleagues, the use of functional magnetic resonance imaging (fMRI) in response to food and food cues has application to explore interventions to address the issue of malnutrition in older adults. The review demonstrates that fMRI offers a valid method for investigating age-related changes to appetite and could provide new and innovative strategies and interventions for malnutrition.⁸ The results will provide an invaluable resource for nutrition researchers looking to apply fMRI methods to their research, opening up an exciting new source of knowledge to tackle malnutrition.

Competence in interpreting statistics is essential for evidence-based practice and a core skill for researchers. The research presented by Coenen and colleagues in this issue provides data on the statistical methods and software most frequently used in published nutrition and dietetics research over the past decade and beyond. The methods to collect the data are innovative: the bag-of-words, text mining approach is an unusual but effective method of finding data on statistical methods across a large sample (more than 750 research articles). The findings are directly applicable to readers involved in preparing entry-level practitioners and researchers and can be used by those who develop professional education curricula for experienced practitioners and researchers.⁹ Similarly, Hutchesson et al report on a survey of dietitians, nutritionists and students about professional development and resource needs in relation to dietary assessment. The findings highlight the dietary assessment methods being used and the resource and professional development needs to build capacity. Of note for the profession is the slow uptake of technology to apply traditionally paper-based dietary assessment methods. They highlight that greater

adoption of technology could go a long way to reducing participant burden.¹⁰ Further opportunities for leveraging technology could lie in the so-called big data harnessed through smartphone applications to explore nutrition and dietetics research questions, which would be a way of reducing research waste and more efficiently adding new knowledge to our discipline. Of course, whilst embracing technology, we also need robust research to ensure the accuracy of technology-based methods when undertaking dietary assessment which will increase confidence in its adoption.

Several papers in the issue are focused on the validation of new tools, across diverse areas of practice and groups. Scrivin et al report on their validation of a newly developed questionnaire looking at exercise-associated gastrointestinal symptoms, a highly relevant issue for dietitians and nutritionists practising in the area of sports nutrition.¹¹ An innovative meal assessment tool's association with energy and protein intake is reported in the article by Tan et al, providing a practice-focused tool for monitoring intake in patients with malnutrition or at higher risk of malnutrition.¹² Mohammadifard and colleagues also report on the validation of a food frequency questionnaire that has been tailored to the Iranian population, and their work highlights the importance of culturally tailoring dietary assessment tools.¹³ Finally, Notaras et al report on the evaluation of the implementation of a previously validated tool to assess dietitians' communication skills provides some practical insights into using tools developed by researchers to improve practice. In particular, the application of peer review to apply the tool in a workplace is ideal for supporting reflective practice.¹⁴

Despite the breadth and depth of research showcased in this issue, there remain underused research methods and a seemingly never-ending list of underexplored areas of research and practice relevant to nutrition and dietetics. In terms of research areas, we can be guided by the research priorities recently identified for Australian dietitians for focus over the next decade. The five priority research themes include healthy ageing, vulnerable populations, food systems and health/nutrition promotion, informatics and evidence based practice, and achieving a balance between prevention and treatment approaches.¹⁵ For selection of research methods, we need to remain open to opportunities to use new methods for our discipline with an eye on broader social trends, whilst continuing our pursuit of quality through internal coherence and other markers of research quality. We hope this issue provides opportunities across the profession to explore research methods not previously realised. The future of research, and our journal *Nutrition & Dietetics*, has never been more promising.

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REVIEW

Using realist approaches in nutrition and dietetics research

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Abstract

Aim: The aim of this study was to explore the use and future potential of realist approaches to research in nutrition and dietetics.

Methods: A targeted literature review was used to search key journals ($n = 7$) in nutrition and dietetics to identify existing research using a realist approach. A narrative synthesis was conducted to explore findings in relation to the research aim.

Results: Nine research papers (four realist evaluations, five realist reviews) describing seven nutrition interventions were found, which revealed the application of realist research in nutrition and dietetics has focused on public health interventions. Realist research provided a deeper, more nuanced understanding of varied outcomes including the role of context, and contributed to the development of theory about how and why interventions work. As a theory-driven research method, realist research was able to assist in overcoming methodological shortcomings to contribute to meaningful, transferable findings.

Conclusion: The results highlight the potential contribution of the realist research in nutrition and dietetics to evaluate interventions and inform future practice.

KEYWORDS

Behavior And Behavior Mechanism, context, dietetics, program theory, review, realist evaluation, realist synthesis

1 | INTRODUCTION

Nutrition and dietetics research spans a wide range of topics across a range of different settings and contexts using a range of different research methodology and methods. With such diversity comes the need for a range of research approaches. Nutrition and dietetics is still

dominated by a positivist approach to research,¹ with randomised control trials (RCTs) perceived as the gold standard in terms of methods.² RCTs are used to explore the effects of interventions.³ While there are a number of benefits to RCT implementation, the ability to explore cause and effect relationships through the use of a control group is its main strength. This is suitable for some areas of nutrition and dietetics research; however, the practicalities of achieving this in other areas are

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markedly different. This is because such research typically takes place in complex settings, where a control group is unfeasible and possibly unethical. In addition, the impact of the human agency element in these interventions introduces confounding variables that can nullify the strengths of the RCT.⁴ Nutrition and dietetics research requires approaches that still allow investigators to explore causation but acknowledge complex and social elements of research in this field. Realist methodology offers an alternative approach.

Realist methodology provides one such approach for dealing with the complexity of nutrition interventions. It is grounded in realist philosophy,⁵ of which the key tenets include: the belief that social reality is real but only knowable indirectly; complex social interventions can act at all levels of context; and, generative causation—‘the theoretical and statistical elaboration of an underlying, generative causal process existing in time and space, including also actors who make decisions within social contexts’.⁶ Broadly speaking, realist philosophy sits on a spectrum between positivist and constructivist approaches. It shares the ontological perspective of a positivist approach that there is a knowable real world, however, epistemologically it sits closer to constructivism. Positivism maintains that only knowledge that is observable is true, while realism and constructivism posit true knowledge as being indirectly knowable. Realism deviates from a completely constructivist epistemology in that it bases knowledge construction on the interpretation of causation.⁷

Realist research is referred to as a ‘theory led’ form of research, whereby the essential premise is that all programs, policies or interventions are ‘theories incarnate’,⁸ that is, when resources are provided in a certain way, to a certain group, it produces certain outcomes.^{9,10} A realist approach has an explanatory focus and is designed to interrogate the ‘program theory’ of an intervention. Such interrogation results in the identification of mechanisms, which are underlying generative causal processes and how they interact with context to contribute to the intended and unintended outcomes of interventions. Statements about the relationship between context, mechanisms and outcomes (referred to as CMO configurations) are developed and contribute to understanding how, under what circumstances and why a complex social intervention may or may not work.⁴ In particular, mechanisms allow the researcher to unpack the ‘black box’ of how and why interventions lead to certain outcomes. This is a key difference from non-realist methodologies and is what makes a realist approach so beneficial.

Pawson and Tilley developed and championed the version of realist methodology discussed in this paper.⁹ They translated realist methodology into practical methods to do evaluation^{11,12} and evidence synthesis.^{8,13}

Realist evaluation usually uses primary data and realist synthesis (or realist review) is a form of systematic literature review⁸ that uses mainly secondary data. In both types, researchers focus on theory as the unit of analysis and synthesise findings to develop, test and refine explanatory program theory about how an intervention, or types of interventions, work across different contexts.¹⁴ Researchers can look across similar program theories to explore patterns that can contribute to the theoretical understanding of these interventions. An intention of realist programme theory building and refining is to arrive at a more ‘Middle-Range’ Theory of the intervention, what Merton, defined as ‘...theories that lie between the minor but necessary working hypotheses that evolve in abundance during day to day research and the all-inclusive systematic efforts to develop a unified theory that will explain all the observed uniformities of social behaviour, social organization and social change’.¹⁵ The development of middle-range theory allows for transferability of findings to programs with similar underlying theories.

A realist approach does not prescribe a specific method for evaluating interventions, instead recommending methods which will best fit the study and provide explanatory data. As such, where positivists traditionally focus on quantitative data, realists are avowedly mixed methods and acknowledge the utility of other data in intervention theory building and refining. This is because these data sources are also particularly valuable for providing important contextual information which is important in realist approaches to help describe how the intervention works and in what circumstances. There is potential for realist research to address difficulties in the current state of nutrition and dietetics research, as it acknowledges the complex and social aspects of an intervention in seeking to explain the underlying causes of intervention effects. It also provides opportunity to scaffold existing theory in nutrition and dietetics, particularly in relation to the interplay of human agency and social interactions foundational to behaviour change.¹⁶ It has also been proposed that despite a heavily theoretical underpinning, development of a causal hypothesis can influence policy makers and make a case for the benefits of social interventions¹⁷ (see Table 3 for a glossary of definitions).

Despite the potential for realist research to address the difficulties in the current state of nutrition and dietetics research, there is a paucity of information about how and to what extent realist approaches are used in the discipline, and to what effect. Therefore, the purpose of this review is to find out how realist approaches are used in nutrition and dietetics research and what impact this had on findings, outcome, and research translation. In presenting this synthesis, we aim to inform the future

potential of realist approaches in nutrition and dietetic research and evaluation.

2 | METHODS

In the interest of trying to summarise how realist research could be useful in nutrition and dietetics, this study employed a targeted literature review and narrative synthesis.¹⁸ Key journals in nutrition and dietetics were identified by the authors as *Journal of the Academy of Nutrition and Dietetics*, *Journal of Human Nutrition and Dietetics*, *British Journal of Nutrition*, *Canadian Journal of Dietetic Practice and Research*, *European Journal of Clinical Nutrition*, *Nutrition Reviews*, *Nutrition and Dietetics and Public Health Nutrition*. The search terms 'realist' and 'realism' were entered into all of the journal websites in June 2020 by the first authors. No date range or restrictions to language or geographical location were applied. Search results were exported to EndNote¹⁹ and full text retrieved. At this stage, the reference lists of exported full-text publications were hand-searched to identify additional relevant publications, which were also exported.

The first authors reviewed all full-text publications in relation to study aim. Only full-text publications that described realist research related to nutrition and dietetics were included. Data extraction for included publications was managed using a Microsoft Excel²⁰ template. One author independently extracted data for included realist evaluation papers and a second author for realist review papers. Extracted data included publication year, location, aim, design, study population, substantive or existing theory about intervention, results (including relevant quotes), how the realist approach impacted the study findings, outcome and research translation and design limitations. The research team then came together to discuss extracted data. During discussions, the research team identified initial impressions on how the approach had been used and what impact the approach had on the study's findings. The first authors then conducted a second review of included papers, with a focus on extending and consolidating the synthesis. Additional data and supportive quotes were extracted in relation to emerging ideas. The final analysis was discussed among the research team who affirmed the findings which are reported below under key headings that summarise the narrative synthesis.

3 | RESULTS

The search identified nine research papers (four evaluations²¹⁻²⁴ and five reviews²⁵⁻²⁹) describing seven

interventions in nutrition and dietetics that applied a realist approach. All were included in the narrative synthesis. Table 1 provides an overview of the key data extracted for the four included evaluations, and Table 2 for the five included reviews. A description of the included interventions is also provided below.

For all included studies, the majority of research came from the UK (n = 6)^{21,24-27,29} with two studies from Canada^{22,23} and one from Australia.²⁸ All were public health interventions focused on primary prevention, including school food and nutrition (n = 3),^{22,23,27} breastfeeding support (n = 2),^{24,25} food literacy (n = 2),^{28,29} and food and nutrition security (n = 2).^{21,26} Most papers identified existing theory about the intervention and its effects (n = 6),^{22,23,25,27-29} including existing formal theory, such as the Health Belief Model³¹ and Social Cognitive Theory,³² or specific intervention theory developed by researchers.

The realist evaluation studies described data collection with diverse participant groups, including the intervention target population/s (n = 4),²¹⁻²⁴ health professionals and/or other stakeholders involved in intervention delivery (n = 3)²²⁻²⁴ or a combination of these (n = 3).²²⁻²⁴ Common research methods were used to gather qualitative data; semi-structured interviews (n = 4),²¹⁻²⁴ questionnaires (n = 3),²²⁻²⁴ observation (n = 3).²²⁻²⁴ None of the realist evaluation studies reported quantitative data collection. All four realist evaluation studies included data pertaining to refined intervention theory. Limitations described were those commonly reported in research, including small sample size (n = 2),^{21,24} low response rate (n = 1)²⁴ or single participant group or geographical setting (n = 3).^{21,23,24}

The number of primary studies included in the five realist reviews ranged from 11²⁸ to 39.²⁹ Quality appraisal was reported in three of the five studies.^{25,26,28} Four of the five studies reported the identification of formal theories.^{25,27-29} Four of the five studies alluded to a lack of contextual information that hindered the development of intervention theories.²⁶⁻²⁹

A number of research papers described varied intervention outcomes in existing research, which required further exploration:

'...little research has elaborated on this in the Canadian context and explored social processes associated with implementation occurring at the level of school districts to help explain how and why district practices may contribute to different levels of policy compliance'.²³

The realist reviews were able to use existing theory in the development of intervention theory. For example, Greenhalgh et al conducted a realist review on

TABLE 1 Summary of the included published realist evaluations from nutrition and dietetics specific journals included in narrative synthesis

Reference	Aim	Setting	Participants	Intervention	Existing theory	Methods	Results	Limitations
Ohly et al ²¹	Explore potential program outcomes and explain how and why these might occur	North West England, United Kingdom Participants were recruited through midwifery services, drop in sessions such as breastfeeding support groups, children's centres and social media	Low income pregnant women	Healthy Start food voucher program, government food relief initiative	Nil	Qualitative Data collected using semi-structured interviews using realist interviews (see glossary)	Outcomes, including intended (dietary improvement) and unintended (shared benefits, financial assistance, stockpiling formula). Influenced by context (women's circumstances, values, beliefs, motivation) Identified and refined mechanisms to explain varied outcomes (eg, prioritising unborn baby or children over themselves)	Most women experienced multiple outcomes and was not able to explain how they overlapped Small sample size and specific participant group limited refinement of other program theories
Levay et al ²²	Answer the question: What processes at school district level drive the implementation of a mandatory school food and drink policy?	Canada Five school-districts in British Columbia, including three urban and two rural	For each district: School-district-level staff, public health stakeholders, private food vendors School-level administrative staff, parents, school food staff and one teacher	School food and drink sales policy	Existing program theory developed by researchers ³⁰ If district-level staff were provided with information about the necessity of improving school food environments and how implementing the policy will fill this need, it would increase motivation to implement guidelines which would lead them to access the implementation tools and other resources, assess existing school food environments and, if needed, make changes to what is for sale in schools.	Multiple case study approach Qualitative data collected using semi-structured interviews, structured questionnaires, observation, website scans	Identified three mechanisms influencing the implementation of policy at school district level 1 Mandatory: Mandatory nature of policy, influenced by normative acceptance of education systems hierarchy 2 Money: Demand leads vendors to create a compliant supply of products, driven by beliefs about children's food preferences, health and food and the existence of competition 3 Monitoring: Systems of informal monitoring are used to promote compliance in the context of a competitive sales environment	Inconsistency of data sources across cases due to variation in how school districts allowed data collection.
Levay et al ²³	Identify key school level contexts and mechanisms associated with implementing a provincial school food and beverage policy	Canada Five school-districts in British Columbia, including three urban and two rural	For each district: Regional and provincial education stakeholders, private food vendors, school administrators, teachers, other school-level staff and parents	School food and drink sales policy	Existing program theory developed by researchers and described above ^{22,30}	Multiple case study approach Qualitative data collected using semi-structured interviews, structured questionnaires, observation, website scans Analysis and coding for CMO configurations within and across case studies	Identified four mechanisms influencing implementation of policy and dimensions of context that influenced these 1 Mandatory: Mandatory policy triggered some actors' implementation efforts, influenced by their normative acceptance of the educational governance system 2 Scofflaw: Some expected implementers had an opposite response to the mandate where they ignored or 'skirted' the policy, influenced by values and beliefs about the role of government and school food 3 Economic: Vendors' responses to school demand for compliance with nutritional guidelines were mediated by beliefs about food preferences of children, health and food 4 Resource constraints: Resource constraints and lack of capacity led otherwise motivated stakeholders to not implement the mandatory policy	Only examined school-level implementation, however school-district level stakeholders examined in Levay 2019 ²²

(Continues)

TABLE 1 (Continued)

Reference	Aim	Setting	Participants	Intervention	Existing theory	Methods	Results	Limitations
Hunter ²⁴	Study the context of breastfeeding support and evaluate a targeted breastfeeding support intervention for young women	United Kingdom Postnatal ward	Health professionals and young (teenage) mothers	Breastfeeding support package, including training staff to deliver structured, proactive breastfeeding support to young mothers in a designated area of the postnatal ward, using checklists adapted from the United Nations Children's Fund (UNICEF) Baby-Friendly Initiative	Nil	Qualitative data collected using pre- and post-training questionnaires, semi-structured interviews, evaluation forms, focus groups and observation of practice	Four principal barriers to young mothers initiating and continuing to breastfeed on the postnatal ward: a disempowering birth experience, the ward as an alien environment, communication problems resulting from different cultural assumptions of young mothers and staff, and pressure to exclusively breastfeed. Young mothers require proactive, empathetic breastfeeding support on the postnatal ward, which both reassures and encourages them. Knowledge and attitudes of maternity professionals can positively or negatively influence young mothers' knowledge, comfort, confidence and therefore establishment of breastfeeding during hospital stay, or not. Thee intervention developed a more positive and enabling attitude of staff towards young women, however, the context of a busy, task-orientated, medical environment negatively influenced the success of the intervention.	Small study sample (15 young mothers), limited geographical setting. Low response rate for some parts of data collection (questionnaires, evaluation forms)

school feeding interventions that explained how and why the findings from a Cochrane review of the same interventions differed across populations, contexts and circumstances.²⁷

Realist research contributed to understanding how and why diverse intervention outcomes may occur. For some interventions, this was the first study to provide a preliminary understanding.

'This study is the first to elucidate possible reasons why women may experience these different outcomes'.²¹

For other complex interventions, realist research built on existing theory and research findings to develop a deeper, more nuanced understanding of the mechanisms that contributed to intervention outcomes and the influence of context. One realist evaluation of school food and drink policy provided insight into how stakeholders responded in different ways based on how they viewed the mandatory nature of the policy (a feature of their context), which then led to varied implementation and compliance. These findings were used to scaffold existing intervention theory:

'Previous studies have found that mandatory nature of policy motivates some school-level stakeholders towards implementation, however, this study found this is not necessarily the case in practice, as some stakeholders were reported to take limited or no action because of their aversion to the paternalistic nature of mandatory interventions'.²³

All five of the realist reviews defined context as being more than concepts of 'geography' or 'place'. Ohly et al used the definition for context provided by Pawson⁸ in their realist review of the Healthy Start Food Voucher intervention. This definition refers to context as having multiple layers: 'individual, interpersonal, institutional and infrastructural'. While the aim of the review was to identify outcomes linked to contexts at all four levels, insufficient evidence to comment on contexts at the institutional and infrastructural levels was reported. Hence the intervention theories presented by the study focused on how individual and interpersonal contexts influenced why the intervention worked.

In Trickey et al's review of breastfeeding support interventions, three separate contexts were identified: social context, infant feeding context and health service context.²⁵ Within each of the selected studies, these different contexts were described. For example, a single study analysed for potential intervention theories highlighted that the intervention took place in Scotland, and the context was defined as 'high levels of deprivation, very low breastfeeding rates, health professionals

ambivalent about breastfeeding...' This description allowed the authors to look for similar contextual attributes across the other included cases.

Included realist evaluation studies also highlighted how context is deeper and more nuanced than setting. Ohly et al identified how participants' response to being given food vouchers were influenced by elements of context at the individual and interpersonal level, such as participants' values, beliefs and motivations about healthy eating.²⁶ In that study, different values, beliefs and motivations about healthy eating shaped how participants used the food vouchers, leading to intended and unintended outcomes.

In a multiple case study approach, Levay et al^{22,23} purposely selected rural and urban districts to explore how context may influence the implementation of a school food and drink policy. Levay sought data to understand how and why a district being 'rural' or 'urban', contributed to understanding differences in policy implementation across these settings. They described how vendor availability is a feature of, and varies between, rural and urban implementation settings (context). If procurement of compliant products (the focus of the study) is not possible, then the ability of an area to acquire them is negatively impacted and the area is seen as non-compliant, despite participants wanting to comply.

In urban contexts there is a high availability of vendors, which can influence availability of compliant products—availability tends to be higher. In rural settings, there are less vendors, therefore procurement of compliant products is more difficult so even where school administrators and volunteers are motivated to implement and comply with the policy, they can be limited by available infrastructure.²³

Each of the selected studies highlighted the benefits of using intervention theory as the unit of analysis. All five of the selected realist reviews emphasised the importance of intervention theory analysis in providing tangible recommendations for policymakers around complex public health interventions. Several authors claimed that the complexity and heterogeneity of these interventions restricts the usefulness of traditional systematic reviews for policy makers.

'Simply knowing that feeding programs work is not enough for policymakers to decide on the type of intervention that should be implemented'.²⁷

'Agency is synonymous with realist mechanisms (the reasoning and reactions of individuals in response to the resources offered by the program), and this review illustrates the contribution of realist methodology to

understanding differential impacts of public health interventions or programs'.²⁶

All four of the realist evaluations also described how the theory-driven approach provided evidence-based, plausible explanations for intervention outcomes, which could be transferable to other interventions. Ohly et al, for example, used findings to develop a theoretical model of change, which could be transferable not only to other food voucher interventions, but other interventions where similar mechanisms may occur.²¹

*'Although this model was based on evidence-based program theories about the Healthy Start program, similar mechanisms relating to prioritisation and reinforced motivation may be transferable to other food voucher programs, and perhaps other types of financial support programs designed to encourage dietary improvement'.*²¹

A potential challenge of realist reviews was identified across several papers, which related to a lack of detailed data about interventions in published studies (ie, what was performed, by whom, to whom, for how long) and a lack of information about why the intervention was expected to work (intervention theory).

*'The attempt to identify intervention theories from the included cases confirms that intervention designs underpinning experimental studies have tended to be undertheorised and highlight heterogeneity among studied interventions. Descriptions of intervention theory were frequently absent from the intervention case materials'.*²⁵

*'...we were unable to distinguish between something that was not done and something that was done but not reported on because of the stringent word count constraints of medical journals'.*²⁷

A number of realist evaluations described a single case study and/or common methodological challenges, such as small sample sizes and challenges with data collection. Levay's study of multiple cases across different geographical settings described inconsistency in the source of data across cases due to variation in how researchers were able to collect data in each school district.²² However, this did not impact on the quality of the findings, as researchers were able to identify the same mechanisms (theory) across cases.

'Regardless of whether it was a principal in one district discussing a particular mechanism or a district office staff in a different district discussing the same mechanism, the mechanisms are the same and conclusions can be inferred as to what contextual factors might actually be influencing

*the underlying mechanisms across context and across individual stakeholders'.*²²

Similarly, realist reviews defined evidence for inclusion as information relevant to the testing and creating of intervention theory. This helped to overcome limitations in the availability of data on a particular intervention theory from traditional sources or study designs. As Harris et al stated:

*'A method that allows the inclusion of a range of different study designs has considerable merit as each design approach may reveal different elements of the intervention are important in fully understanding the mechanisms, and how they are shaped by context and to what types of outcomes these might lead'.*²⁹

Indeed, Harris et al went beyond using published data and incorporated stakeholders into the theory development process. The following quote also emphasises how a realist methodology provides much-needed insight into how, why, for whom and under what circumstances complex interventions succeed or fail:

*'Consulting with stakeholders became a critical part of the process because studies tended to focus on tangible processes and formally measurable outcomes. Informal or tacit information relating to interpersonal relationships and the subtle contextual conditions that may cause interventions to succeed or fail but were often missing from the papers'.*²⁹

The transferability of realist review findings were also demonstrated. When analysing the included interventions Harris et al analysed studies individually, then compared them to develop transferable intervention theories.²⁹ These intervention theories were then scaffolded with formal theories relevant to health literacy. There were no examples across all included studies of interventions where research findings were reported to be translated to practice.

4 | DISCUSSION

This manuscript aimed to synthesise how realist approaches have been used in nutrition and dietetics research and what impact this had on findings, outcome and research translation. A targeted search of nutrition and dietetics specific journals identified four realist evaluations and five realist reviews. A narrative synthesis was carried out that described how realist research provided a deeper understanding of varied outcomes and the role of context in how and why interventions work. The findings of this study highlighted the importance of theory driven methods, the need to think differently about study quality and how realist findings could inform practice. In doing so, this study shows the

potential value in realist approaches for nutrition and dietetics research.

Realist research is well suited to complex, social interventions and this is reflected where realist research has been used in nutrition and dietetics to date. All manuscripts in this study described public health nutrition interventions, which are typically defined by a focus on understanding and addressing determinants of nutrition and health-related status in populations.³³ Public health nutrition practice also involves significant complexity as multiple, shifting determinants interact in different ways across diverse populations and contexts. Furthermore, it could also be argued that all areas of nutrition and dietetic practice are intrinsically complex in terms of the science of food and nutrition and the systems which dietetic practice must navigate, including health care and food systems.³⁴ As such, realist research is well placed as an approach to investigate and develop solutions to issues across all areas of nutrition and dietetic practice.

Food service is arguably an area of practice filled with complexity, as it spans health and food service systems, with multiple actors and competing drivers across sustainability and economics.³⁵⁻³⁷ Food service is also key to tackling malnutrition, a long-standing global issue, across settings including hospital and aged care.³⁸ Furthermore, malnutrition is complex; determinants of malnutrition are multifactorial and not presently well understood.³⁹ Traditionally, research in this area has focused on building a common understanding of the aetiology of malnutrition³⁹ and a recent systematic review concluded the need for more RCTs to provide high-quality evidence.^{40,41} However, given the complexities of malnutrition, an understanding of how it occurs across different contexts, and interventions that reflect this, could prove beneficial. Realist research offers such an approach to contribute to the development of effective interventions across food service and other practice areas to address malnutrition in the long term (Table 2).

Diverse outcomes of nutrition and dietetic interventions were illustrated in this study, both in realist reviews of existing published evidence and in empirical findings of realist evaluations. This is not surprising; diverse outcomes have been reported across many areas of nutrition and dietetics, including interventions in clinical practice.⁴² However, this study highlighted how realist research can make a unique contribution towards understanding how and why interventions outcomes may differ. These findings suggest that realist research can contribute to identify gaps in existing nutrition intervention research, in particular, a lack of information about context. A realist research paradigm anticipates varied outcomes, on the premise that interventions are complex, operating in complex environments, with broader social,

political and economic contexts that are multifactorial and diverse.⁴³ As such, realist researchers focus on understanding how context can influence mechanisms to produce outcomes. All of the included papers in this study gathered and analysed data pertaining to contexts and their interactions with underlying mechanisms. It was also observed that context was interpreted and operationalised in different ways across the studies, including context at multiple levels, similar to the socio-ecological determinants of health,⁴⁴ and defining specific contexts related to the intervention and setting. This reflects the way that realist research can explore context as it is relevant to the intervention theory. Overall, the focus on context in a realist approach facilitated a deeper understanding of how and why interventions work in different ways to produce wholly different outcomes, according to context.

Dietetic practice spans a diverse range of areas, however, as with many disciplines, research and in particular translation of research findings tends to be siloed. As a theory-driven approach, realist research provides opportunity to connect research across practice areas. Researchers may draw on evidence across different types of interventions, where similar mechanisms may contribute to intervention outcomes. Similarly, there is a level of generalisability of realist research findings, as rich, explanatory theory about how and why interventions work across different contexts can be transferable to other interventions, including similar interventions and those that are somewhat different.⁴⁵ This was reflected in this study, for example, as Ohly et al suggested that the theory about how and why women use food vouchers in different ways, based on context, which contributes to both intended and unintended outcomes, could be transferable not only to other food voucher interventions, but also other types of financial support interventions. These findings support the notion that realist research can provide portable theory about interventions and that findings can span across seemingly different interventions or practice areas to provide lessons there. In this way, realist research can support the ongoing accumulation and transfer of knowledge in nutrition and dietetics and break down research siloes.

The focus on theory as the unit of analysis also means that realist research can draw on diverse evidence that may not be captured by other research methods.^{46,47} Realist evaluations in this study were able to use data that would traditionally be considered lower quality, to contribute to rich theory building. Realist evaluation does not prescribe specific methods. In traditional hierarchies of evidence, whereby RCTs are considered the gold standard, qualitative research is perceived as less rigorous.^{8,48,49} Interestingly, all of the realist evaluations in

TABLE 2 Summary of the included published realist reviews from nutrition and dietetics specific journals included in narrative synthesis

Reference	Aim and/or research questions	Setting and intervention	Methods	Quality appraisal	Formal theories identified	Results—Program Theory	Limitations
Trickey et al. ²⁵	<p>1. To explore heterogeneity in theoretical underpinnings and in intervention design among one-to-one breastfeeding peer support interventions;</p> <p>2. To inform design decisions by identifying transferable lessons developed from cross-case comparison of context-mechanism-outcome (CMO) relationships</p> <p>3. To inform evaluation design by identifying CMO relationships associated with experimental conditions.</p>	<p>United Kingdom</p> <p>Maternal and child nutrition</p> <p>Breastfeeding peer support interventions</p>	<p>Fifteen intervention cases were identified from searching index experimental studies.</p> <p>United States of America,⁹ United Kingdom,⁵ Canada¹</p>	<p>Quality was considered compromised where the following were lacking: (a) description of intervention theory, (b) description of intervention components, (c) a description of the infant feeding and health service context, (d) description of implementation, take-up, and fidelity issues, (e) existence of process evaluation, and (f) congruence between measured outcomes and intervention theory.</p>	<p>Social learning theory</p>	<p>This review indicates strongly that breast feeding peer support intervention design should incorporate theories (and associated intended mechanisms for change) operating at higher ecological levels.</p>	<p>Quality of included papers varied, and this review is limited to one on one peer support theories</p>
Ohly et al. ²⁶	<p>To explore how low-income pregnant women use Healthy Start food vouchers, the potential impacts of the program, and which women might experience these impacts and why:</p> <p>How do low-income pregnant women use Healthy Start vouchers?</p> <p>What are the intended and unintended outcomes of the program?</p> <p>What are the underlying mechanisms and how do variations in context influence (enable or constrain) these mechanisms?</p>	<p>United Kingdom</p> <p>Maternal and child nutrition</p> <p>Use of Healthy start vouchers by low-income pregnant women</p>	<p>38 primary studies were included: four studies on Healthy Start program and 34 studies on Women, Infants and Children program.</p> <p>Two main outcome strands were identified: dietary improvements (intended) and financial assistance (unintended).</p>	<p>An assessment of 'rigour' was used to judge the credibility and trustworthiness of the evidence as it was integrated into the analysis and synthesis</p>	<p>No formal theories identified</p>	<p>Substitution effects: economics of decision making; responsible subversion</p>	<p>Lack of evidence to link program theory with sociodemographic and cultural characteristics, such as which groups of women are more/less likely to value healthy eating</p>
Greenhalgh et al. ²⁷	<p>To determine what works, for whom and in what circumstances for trials of school feeding programs in disadvantaged children.</p>	<p>United Kingdom</p> <p>School feeding programs</p>	<p>18 studies (reported in 29 articles) were used to analyse four broad areas: historical context of school feeding programs; theories explaining their success, particle success, or failure and measurement issues</p>	<p>None reported</p>	<p>Correction of nutritional deficiencies theory</p> <p>hunger relief theory</p> <p>benevolent attention</p> <p>reduced absenteeism</p> <p>inspires improved home diet improved literacy reduces intergenerational cycle of poverty</p>	<p>Programmes should be aimed at children with documented nutritional deficiencies</p> <p>Programmes are more likely to be effective when designed in partnership with the local community and interventions are piloted</p> <p>In situations of absolute poverty even severely malnourished children may not benefit from school feeding programmes because they may receive less food at home</p>	<p>Limited by not including descriptive studies, theoretical papers, and grey literature.</p>

TABLE 2 (Continued)

Reference	Aim and/or research questions	Setting and intervention	Methods	Quality appraisal	Formal theories identified	Results—Program Theory	Limitations
Maugeri et al ²⁸	To explore for whom and under what circumstances nutrition education cooking interventions affect nutrition outcomes in adults.	Australia Cooking programs to improve public health	11 programs included in this review. Programs meeting the search criteria were from 6 countries: Australia, Brazil, Canada, United States of American, England and Scotland.	Relevance and rigour	Social cognitive theory	A total of 7 context-mechanism-outcome configurations (CMO-Cs) were identified across the 11 programs, building on the initial program theory of 4 CMO-Cs relating to the nutrition-education cooking intervention strategies of hands on cooking, a skilled facilitator, and incorporating food access and family support	Lack of contextual depth in published papers
Harris et al ²⁹	To undertake a participatory realist synthesis to develop a better understanding of the potential for community-based peer support to promote better health literacy and reduce health inequalities. What approaches to community engagement are most effective in promoting peer support, to which people and in what circumstances? How does community-based peer support impact on understanding of existing health information and the use of health information and health services to improve health and reduce health inequalities?	United Kingdom Community-based peer support to improve health literacy	Programs were selected based on context (within the United Kingdom) ³⁹ and then categorised into one of seven 'clusters'.	Stakeholder consultation provided further contextual information to the studies	The health belief model, theory of planned behaviour, and social cognitive theory; self-regulation with peer or social support.	Conditions of disparity compromise the relevance and uptake of the intervention, potentially disempowering peer supporters and participants alike. The reporting of linkages between mechanisms and outcomes was incomplete. This meant that configuration was required in order to hypothesise what the associations might be	

TABLE 3 Glossary of key 'realist' terms

Key term	Definition
Context	'Context often pertains to the "backdrop" of programs and research. ... As these conditions change over time, the context may reflect aspects of those changes while the program is implemented. Examples of context include cultural norms and history of the community in which a program is implemented, the nature and scope of existing social networks, or built program infrastructure. ... They can also be trust-building processes, geographic location effects, funding sources, opportunities, or constraints. Context can thus be broadly understood as any condition that triggers and/or modifies the behaviour of a mechanism'. (p. 317) ⁴⁶
Mechanism	'...mechanisms are underlying entities, processes or structures which operate in particular contexts to generate outcomes of interest'. ¹³ 'Mechanisms are the agents of change. They describe how the resources embedded in a program influence the reasoning and ultimately the behaviour of program subjects.' (p. 13) ⁵
Outcome	'Outcomes are either intended or unintended and can be proximal, intermediate or final... Examples of intervention outcomes are improved health status, increased use of health services, and enhanced research results.' (p. 317) ⁴⁶ They are what occurs when a mechanism is activated.
Theory	There are multiple definitions for the word 'theory'. One simple definition is that, 'A theory is an attempt to organize the facts—some 'proven', some more conjectural—within a domain of inquiry into a structurally coherent system'. ¹⁰
Substantive theory	'Existing theories within particular disciplines. They may be used to help understand interventions. For example, in the social sciences theories may deal with topics such as "cognitive development," "deviance control," "incentivisation" or any of the wider ambitions of interventions'. (p. 15) ⁵²
Middle Range theory	'A theory that is specific enough to generate hypotheses (eg, in the form of propositions) to be tested in a particular case, or to help explain findings in a particular case, but general enough to apply across a number of cases or a number of domains'. (p. 15) ⁵²
Program theory	'This is the theory about what a program or intervention is expected to do and in some cases, the theory about how it is expected to work. Realist program theory goes a little further and includes descriptions of contexts, mechanisms and outcomes'. (p. 10) ⁵²
Realist evaluation	'Realist evaluation uses mainly primary data. The evaluator ventures into the field and collects data in order to develop, test and refine a programme theory to explain for whom and in what circumstances and why an intervention or programme works'. (p. 2) ¹¹
Realist synthesis/review	'Theory based approach to synthesising existing evidence'. ⁵² 'It is a form of systematic literature review... Realist synthesis uses mainly secondary data... The purpose is to synthesise findings from these studies and other relevant data to test and refine theories which explain in what circumstances and through what underlying causal processes interventions produce intended and unintended outcomes'. (p. 2) ¹¹
Causation	Causation is about 'what causes what to happen'. (p. 1) ¹² 'The process whereby an outcome (O) of interest was generated by relevant mechanism(s) (M) being triggered in context (C)'. (p. 17) ⁵²
Context-mechanism-outcome configuration	CMO configuring is a heuristic used to generate causative explanations pertaining to the data. The process draws out and reflects on the relationship of context, mechanism, and outcome of interest in a particular program. (p. 316) ⁴⁶ In a sentence, they take the form of 'In "X" context, "Y" mechanism generates "Z" outcome'. (p. 13) ¹³ A simple example of a CMO configuration is as follows: A community experiences a high level of unemployment to which an employment training program is offered (context). But the program has low enrolment and attrition (outcome). The reason is that people have difficulty getting to the venue, owing to a lack of public transportation (mechanism). (p. 316-317) ⁴⁶
Realist interviews	'Theories are placed before the interviewee for them to comment on with a view to providing refinement. The subject matter of the interview is the researcher's theory and interviewees confirm, falsify, and refine this theory. This relationship—described as a teacher-learner cycle—is integral to realist evaluations.' (p. 1) ⁵³

this study gathered qualitative data and none reported quantitative data collection. Researchers also reported a small sample size, lower response rate and limited case settings. However, realist research was able to aid in overcoming what would traditionally be considered study limitations, as the quality of the data was determined by how it contributed to theory building and testing. Similarly, the use of a realist review, compared to a systematic review, by Harris to investigate community-based peer support in relation to health literacy allowed researchers to use 'grey' evidence gathered through stakeholder consultation. This provided key contextual information, which contributed to refined intervention theory, such as how conditions of disparity can compromise the relevance and uptake of the intervention and subsequent outcomes. These examples demonstrate how realist research requires a shift in thinking about research, focusing on how data contributes towards theory development, rather than only whether it is reproducible. In doing so, diverse data collection methods can be utilised in developing meaningful, transferable findings.

None of the studies included in this narrative study gave in-depth consideration of implementation of findings and this is an area in need of development in realist research. It has been proposed that realist research can provide practical and tangible recommendations to policy makers, particularly when planning and implementing interventions.¹⁴ However, realist research does not provide simple answers about whether interventions work or not,¹⁴ instead providing rich, explanatory theory of how and why interventions work across different contexts. Therefore, translating realist research to policy involves a different way of thinking about interventions and intervention findings; there is no one-size-fits-all approach. It is acknowledged that knowledge translation is a broad field; one scoping review conducted by Haynes et al. looked at the capacity of policy makers to use research findings, and found that among other factors, the usefulness of research to policy makers is context-specific and based on more than just academic hierarchies.⁴³ Therefore, realist research, in common with other forms of research, is subject to the context in which it is conducted, including characteristics of the policy makers, communities, organisations and broader environment. It is important, as with any research, that realist research is presented in a way that is easy for policy makers to understand and translate.⁵⁰ It is proposed that the applicability of realist research is that it takes into account context within the research and provides situation-specific wisdom,⁵¹ developing knowledge that matters locally. However, despite the promise of realist approaches to be more useful to decision makers, it was

not a focus of any of the papers in this study and is an area of further research both in nutrition and dietetics but also more broadly, to better understand if and how that occurs (Table 3).

This narrative synthesis of realist research in nutrition and dietetics has described how realist approaches have been used and highlighted future opportunities. Realist research is well placed to deal with the complexities of dietetic practice through a focus on theory about how and why interventions operate in different contexts to contribute to diverse outcomes. Future application of realist approaches could advance researchers' and practitioners' understanding of complex interventions and inform practice to contribute to meaningful outcomes.

AUTHOR CONTRIBUTIONS

The study was initially conceptualised by CP, an APD with extensive experience in health education research together with GJ and IM, APDs with experience in realist research. The researchers further developed and refined the study aim and strategy collaboratively with RH, who has significant expertise in realist research. GJ and IM were responsible for managing the study. The four researchers met regularly throughout the research and CP and RH provided expert review and input at key stages. All authors have approved this manuscript for submission and have not submitted this manuscript or parts of this manuscript elsewhere.

CONFLICT OF INTEREST

Clare Palermo is an Associate Editor for Nutrition & Dietetics. 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. There are no other conflicts of interest to declare.

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REVIEW

Internal coherence matters: Lessons for nutrition and dietetics research

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Abstract

Aim: Internal coherence in research refers to the alignment between ontology (nature of reality), epistemology (nature of knowledge), axiology (values), methodology and methods and is an important but often overlooked element of research quality. We therefore aimed to illustrate the concept of internal coherence in nutrition and dietetics research, and its importance beyond individual elements of study quality.

Method: A targeted literature search in *Nutrition and Dietetics* was used to identify research illustrating one example of three main approaches to research (scientific, interpretive and critical inquiry) published between November 2017 and November 2020. Studies were included if they related to education research based on the expertise of the authors, and illustrated diverse points about internal coherence. The authors independently critiqued included studies for internal coherence and synthesised their findings.

Results: From 76 manuscripts, 14 were identified as describing education research. Of the three selected studies that were critiqued, all had elements of internal coherence, in particular alignment between epistemology and methodology. However, each had elements of misalignment too, specifically between epistemology, axiology and method. The results point to the profession's historical groundings privileging the scientific approach, showing how this can yield misalignments, particularly when describing the limitations of interpretive and critical inquiry approaches.

Conclusion: This review demonstrates the importance of internal coherence as a marker of quality, over and above existing quality assessment checklists for qualitative and quantitative methodologies. As such, it can help authors, reviewers and editors to improve the quality of nutrition and dietetics research and its reporting.

KEYWORDS

epistemology, editorial policies, qualitative research, methods, peer review, social research

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1 | INTRODUCTION

Nutrition research has evolved from a foundation in biomedical sciences towards its more recent recognition as a social science.¹ Key movements including, but not limited to, the New Nutrition Science have criticised *nutritionism*, and argued for recognition of social and environmental determinants of food and eating behaviour and choice.^{2,3} Alongside this transition, nutrition and dietetics research now preferences whole of diet approaches acknowledging complexity, rather than focusing on single nutrients.⁴ However, nutrition and dietetics research remains somewhat “reductionist”.² It typically focuses on hypothesis-driven questions determining causal pathways based on a philosophy that views knowledge as part of a reality distinct from individuals and demonstrable through scientific methods that largely employ quantitative approaches.^{1,3,5} This *scientific* (or *positivist/post-positivist*) approach has dominated nutrition and dietetics research for the past century, despite widespread acknowledgement that nutrition is environmentally, socially, culturally and historically bound and thus involves both art and science, yet there remains little appreciation of what the “social” involves.²

Given that many research questions in nutrition deal with the complexities surrounding diets, dietary behaviours and knowledge translation into practice, and the interaction between people and society,¹ different approaches are needed. Consequently, there have been calls to move nutrition research away from positivist approaches towards those encompassing the social, cultural, economic, geographical and political influences on nutrition.^{2,6} There has been recent criticism that nutrition research continues to focus on linear biological causes and classifications in nutrition and the need to focus on wider influences on nutrition to create effective practice and policy solutions remains.³ A range of research approaches are embraced in nutrition and dietetics research to address this complexity.

While methods are usually reported well, often researchers typically overlook making explicit their underpinning philosophies and/or misalignment exists between their philosophical stance and their methodology and methods.⁷ Quantitative research has not been subjected to the same level of scrutiny as qualitative research.⁸ Regardless of approach it is important that internal coherence is considered within both qualitative and quantitative research. Internal coherence refers to

the alignment between the philosophy, methodology and methods of research.^{9,10} Misalignment of these features of research can result in researchers not fully addressing their study aims or research questions. Although qualitative and quantitative approaches traditionally sit within certain philosophical standpoints, this is not always the case. With increased expectations for mixed methods research approaches in nutrition and dietetics, alongside the recognition that theory cannot be neatly separated from practice, all researchers must consider internal coherence matters within their research.

To embark on social science research, researchers must understand the theoretical assumptions of their research. Social science requires sound methodologies and methods, together with clear justification of chosen approaches.⁹ This requires acknowledgement that all research is grounded within a certain stance providing context and directly influencing the research. This means acknowledging that in all research—across quantitative, qualitative, and mixed methodologies—reality and knowledge are conceptualised differently. A research approach consists of five components: ontology, epistemology, methodology, axiology and methods (see glossary Box 1).⁹

Ontology, or the nature of reality, is the building block of research and requires reflection on the assumptions of what is real. For example, in the scientific approach typically used in nutrition research, researchers are often seeking a single reality.⁹ Epistemology, or the nature of knowledge, answers the question “how do we know what is true?” For example, in the scientific approach typically used in nutrition research, the epistemology is objectivity, that is, knowledge is believed to exist outside of human consciousness. Epistemology requires researchers to reflect on how they engage in research, the values, as well as the methodology (process of constructing data that generates the knowledge) and methods (the tools) they use to develop knowledge.^{8,9,11} We argue in this manuscript that these principles, while ever present in all research, are rarely made explicit in nutrition research despite informing methodology and methods. The internal coherence or alignment between these elements are the focus of the remainder of this discussion paper. Internal coherence is important as it makes clear the conventions of the research to support interpretations and enhance quality.

BOX 1. Glossary: Abbreviated glossary of terms underpinning internal coherence and research quality. See also Table 1 for examples of these terms

Axiology—values that underpin the research.⁵¹

Confirmability—confidence that data represents participants' perspectives rather than those of the researcher.⁵²

Credibility—believability of findings.⁵²

Dependability—applicability of findings at other times.⁵²

Epistemology—nature of knowledge and knowing.⁹

Generalisability—extent to which the findings of a study can be applicable to other settings.⁵²

Method—approaches to collecting evidence.⁹

Methodology—how we develop the knowledge or theories about how research should proceed.¹⁰

Ontology—what is real and the nature of reality. Relates to people's understanding of the nature of the world.⁹

Reflexivity—understanding one's own position in order to gain insight into the perspectives of others. Articulates researchers' assumption, offers questions and calls attention to how knowledge is created.⁸

Reliability—consistency and accuracy of data.⁵³

Transferability—the applicability of the findings to other populations or groups.⁵⁴

Validity—data received are indicators of the construct being measured.⁵³

Three prominent approaches or philosophies to research are scientific, interpretivist and critical inquiry. Descriptions of the ontology, epistemology, methodology and axiology of these three approaches are defined in Table 1. In summary, scientific (also called positivist) approaches view knowledge as objective, that is, there is one truth to be discovered. Post-positivism is closely aligned with positivism but acknowledges that while objective truth exists, it is unlikely to be fully comprehended as measurements are flawed.¹² Positivist and post-positivist approaches are valuable in specific situations, for example, researchers wishing to explain the effectiveness of an intervention or tool. While those

applying scientific approaches are rarely explicit in their philosophical assumptions or standpoint from which their research questions are derived, they do begin their studies with a theory, typically developed from observations or understandings drawn from existing research producing a formal hypothesis to be tested.^{12,13} Interpretivist approaches, on the other hand, see knowledge as subjective, something that is developed through social interaction.¹⁴ Its value is in acknowledging the role of the individual's experience and interpretation in creating understanding (or knowledge). Critical approaches view knowledge as cultural, with researchers seeking to challenge the status quo and facilitate change in this approach.¹⁵ Critical approaches aim to uncover underlying structures (including geographical, historical, social, cultural, environmental and physical) influencing the concept being researched.¹³ The value of critical approaches has been recognised in the critical dietetics movement, which is dedicated to focusing our attention on issues of privilege, power and marginalisation in dietetics.^{1,16} Choice of approach can be based on the purpose of the research, researchers' positioning within research processes, and research questions.

Research quality is important, influencing both future research and the knowledge applied to practice. Qualitative and quantitative research have different purposes, so consequently have different markers of quality. Consistent with evidence-based practice, there has been greater focus on standardised approaches to evaluating research papers for quality. Criteria for assessing rigour are available for both qualitative and quantitative research.^{17–20} Quantitative assessments involve appraisal of validity, reliability, bias and generalisability.²⁰ Quality assessment in qualitative research focus on rigour markers including dependability (verifiable), credibility (reliable author interpretations), confirmability (researcher personal position transparent) and transferability (sample transferable to other contexts).²¹ Qualitative researchers have suggested ways of describing rigour that go beyond checklists that arguably privilege scientific approaches.⁷ Regardless, such quality markers alone are insufficient, if philosophical position is ignored.

In summary, internal coherence matters. The connection between epistemology, methodology, axiology and method, which ensure internal coherence is as important as checklist markers of quality in research. Researchers must consider their relationship with study participants when considering their philosophical standpoint. Epistemology influences both choice of methodology, axiology, and how methods are implemented and analysed.²² The methodology is the key tenet that informs study design, aims and research questions, and the steps taken in the research process, as well as connecting the research with

TABLE 1 Prominent research approaches in dietetics research

Element of approach*	Scientific	Interpretivism	Critical inquiry
Overview	Objective truth, proof and causation	Human social interaction in life	Political, ideological factors and power within society; promoting change
Purpose is to...	Explain or Predict, eg, <i>What is the relationship between...?</i> <i>What factors relate to...?</i> <i>What is the effect of...?</i>	Understand, eg, <i>What are the views of...?</i> <i>What are the experiences of...?</i> <i>How do stakeholders understand...?</i>	Emancipate, facilitate change, eg, <i>What structures (political, cultural, power) underpin oppression of a group?</i> <i>How might this group be empowered?</i>
Theoretical perspective	"... embraces certainty, seeks universal laws that govern behaviour, and argues an objective external reality that can be accurately and thoroughly understood" ^{12,p695}	"... looks for culturally derived and historically situated interpretations of the social life-world" ^{9 p67}	"... to question the assumptions of dominant forms of thinking by challenging the power relations..." ^{13,p843}
Ontology What is real and the nature of reality	Typically Realism Reality is singular, tangible, identifiable and measurable	Typically Relativism Reality is multiple and based on context, past experiences, etc.	Typically Historical Realism Reality is multiple, shaped by structures, and language can only help partially understand reality
Epistemology Nature of knowledge and knowing	Objectivity; Separation between researchers and research participants (research conducted from the outside)	Subjectivity, Co-construction of knowledge between researcher and participants (research conducted from the inside)	Collectivity, Privileges participant voice (research conducted alongside participants as co-researchers)
Methodology How do we develop knowledge	Examples: Randomised/non-randomised controlled trials, Cohort studies, Case control studies	Examples: Ethnography, Phenomenology, Constructivist Grounded Theory	Examples: Participatory Action Research, Video-Reflexive Ethnography
Axiology/Values Values that underpin the research	Objectivity, Dualism	Language, Social interaction, Context	Democracy, Egalitarianism, Emancipation, Change
Method Approaches to collecting evidence	Typically quantitative (eg, dietary intake, anthropometry)	Typically qualitative/ naturalistic (eg, interviews, observation and documents)	Typically naturalistic/ qualitative and participatory (eg, participatory focus groups, photo-voice)
Rigour	Validity, Reliability, Statistical power, Generalisability	Dependability, Credibility, Confirmability, Transferability, Reflexivity	Emancipatory potential, Dependability, Credibility, Confirmability, Transferability, Reflexivity
Sample	Sample size powered to detect effects	Sample size for information power ⁴⁹	Sample size powered to facilitate change

*Note: The summary presented in this table is largely based on our synthesis of key references.^{9,12-14,50}

theory and the broader discipline.¹⁰ Thus, when embarking on nutrition research, a researcher must first choose their epistemological position, then select their methodology (or elements of existing methodologies), consider axiology, then select methods consistent with the chosen epistemology, methodology and axiology to produce the best data to answer the research questions.¹⁰ Finally, the researcher must apply their approach, mindful of markers of rigour consistent with their chosen approach, rather than different approaches with alternative ways of understanding reality, knowledge and how knowledge should be created. This research therefore aims to illustrate the concept of internal coherence and its importance beyond individual elements of study quality through critique of selected research from this journal. This paper also hopes to support peer reviewers and editors to provide constructive feedback regarding research quality and internal coherence.

2 | METHODS

A targeted literature search based on PRISMA guidelines was used to identify published research illustrating the three chosen prominent research approaches, as well as diverse points about internal coherence. The authors, with collective experience in health professions education research using primarily interpretive approaches, focused on identifying studies that, given their backgrounds, they could effectively critique. Therefore, only manuscripts describing the scholarship of teaching or learning, or credentialing/registration, or education were included such that an informed critique of internal coherence could be made. A simple electronic search was performed within PubMed to identify relevant articles. Studies were considered for inclusion if they met all of the following criteria: any original study focused on dietetics education or credentialing, published in the journal *Nutrition and Dietetics*, with a publication date between November 2017 and November 2020, and where the manuscript provided opportunities for illustrating diverse points about internal coherence. The inclusion of studies only published in *Nutrition and Dietetics* aimed to offer critique and a quality improvement process for the journal given that two of the authors are on the Editorial Board of the journal.

The following search terms were used: “Nutr Diet”[jour] AND dietetics AND (credential OR examination OR workforce OR education). Results were screened by title and abstract, with those included at this stage being assessed against the eligibility criteria through full text review. Articles were excluded if they were an editorial or commentary, review, reported a single case study, or were not a full research paper. Short reports, including

letters to the editor, were only included if the paper was at least two pages in length, detailed the methods used, and reported study findings.

Three studies (one from each of scientific, interpretive and critical approaches) were selected based on the inclusion criteria and especially the manuscripts' abilities to illustrate the stated philosophy and be critiqued for internal coherence. Data were extracted in duplicate from each of these three manuscripts including title, research approach, aim, methodology, methods and key findings. All authors reviewed the manuscripts making notes critiquing issues of quality including internal coherence. These notes were synthesised and summarised into the following analysis by all authors.

3 | RESULTS

The search yielded 76 manuscripts published between November 2017 and November 2020, with 58 excluded through title and abstract screening. The remaining 18 potential articles underwent full text review and were assessed against the eligibility criteria, resulting in 14 included articles describing dietetics education or credentialing research. Of these studies, three focused on competency standards,²³⁻²⁵ four on assessment,²⁶⁻²⁹ five on curriculum,³⁰⁻³⁴ and two on continuing education^{35,36} (Table 2 and Figure S1). These characteristics were reviewed by the authors with the aim of identifying one published example from scientific,²⁸ interpretive³¹ and critical²⁴ approaches that could best illustrate the stated philosophy and be critiqued for internal coherence. The selected papers are summarised in Table 2 and discussed critically below; initially presenting a summary of their study aims and approaches and then critiquing their internal coherence in line with their approaches. We first highlight their strengths before identifying issues with their internal coherence.

Scientific approach: Parkin and Collinson²⁸ took a *scientific* approach to examine the relationship between objective structured clinical examination (OSCE) performance and placement performance. They also sought to understand students' perceptions of the benefits of their OSCE. The first aim is clearly scientific in its philosophical orientation; reflective of how this is phrased in their abstract (Does the OSCE *predict* placement outcome?). Their second stated aim (student *perceptions* of the benefits of the OSCE in preparation for practice) however is arguably not scientific (implying multiple perceptions of reality). As is typical of scientific approaches, the authors use the existing literature to develop a hypothesis for their research. The values (axiology) of the research are implied through the use of purportedly objective measures.

TABLE 2 Key characteristics of three studies selected for critical analysis

Reference (Methodology)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Focus; Aim(s)	Data collection	Data analysis	Results reported	Conclusion
Parkin and Collinson ²⁸	Approach not stated; Survey; Some IC	Assessment; To explore whether an OSCE predicts dietetic placement outcomes and student perceptions of the benefits of the OSCE in preparation for practice	Questionnaires, OSCE outcomes, Placement outcomes	Frequency (percentages), ANOVA	The overall OSCE score was associated with student placement outcomes. Those who struggled during, or failed the placement, achieved similar OSCE scores. 36% (9/25) of students who failed an active station on the OSCE did not pass placement. Students found the OSCE stressful but there was evidence of reduced stress over years.	The OSCE is a meaningful assessment of practical skills, which provides some prediction of placement performance, particularly for active stations.
Morgan et al, 2019 ³¹	Social constructionist epistemological position; Qualitative description; Some IC	Curriculum; To explore the experiences of, and challenges faced by, academic dietetics educators in preparing dietitians for the workforce	Interviews	Thematic analysis	One overarching theme (Aiming for a moving target) and three sub- themes: 1. Striving for betterment 2. Bridging dissonance 3. Distressing impossibilities	Dietetic educators face challenges in preparing a workforce equipped for diverse dietetic practice areas.
Palermo et al, 2019	Critical approach; Action Research; Some IC	Fellow credential; To describe the characteristics of a Fellow and critically review factors relevant to recognition and promotion of excellence within the Australian dietetics profession	Focus groups	Thematic analysis, drawing on CHAT	Four themes: 1. Fellow is associated with leadership 2. Credential is out of reach 3. Never be good enough 4. Lack of recognition deters application	Changes to the system are required to promote uptake of the credential by the profession.

(Continues)

TABLE 2 (Continued)

Reference (Methodology)	Focus; Aim(s)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Data collection	Data analysis	Results reported	Conclusion
MANUSCRIPTS NOT SELECTED FOR DEEPER ANALYSIS (<i>n</i> = 11 listed alphabetically)						
Ash et al, 2019 ²³	Competence; To explore how a competency-based education framework influenced competency standards and how competency-based education has influenced dietetic practice in Australia since 1990	Approach not stated; Qualitative investigation; IC	Reanalysis of previously collected data over time; (1) Interviews with new graduates and guided discussion groups with graduates and employers; (2) competency standards and accreditation manuals/standards	Thematic analysis (interviews and groups), content analysis (documents)	Four themes evolving longitudinally: 1. Communicating for better care 2. Scientific enquiry for effective practice 3. Critical thinking and evidence-based practice 4. Professionalism	Competency-based education has promoted an outcomes focus from 1993 and continues to influence curriculum, assessment and accreditation policy.
Bacon et al, 2018 ²⁶	Assessment; To evaluate a Consensus Model for competency-based assessment	Constructivist-interpretivist; Delphi and Qualitative description; IC	Three-round modified Delphi process, focus groups, interviews	Level of agreement, proportions for Delphi, thematic analysis for groups/interviews	Final assessment of assessor panel disagreed with at least one placement educator for 34% of students, while students and capstone outcomes agreed with assessor panel Consensus model supports sustainable assessment practices	Findings support an interpretivist approach to assessment that uses evaluation as a catalyst for learning, is holistic and uses a panel of assessors for high-stakes decisions.
Butler et al, 2018	Curriculum; To identify how students in Australian tertiary dietetics programs are being prepared to provide services to those with disabilities	Approach not stated; Mixed methods descriptive approach; Some IC	Survey comprising 8 open-ended questions	Inductive “category themes” were quantified; descriptive statistics applied to most frequently occurring themes	12 out of 14 programs included at least one curriculum opportunity that included disability 8 out of 14 programs reported a disability specific lecture 9 out of 12 participants described their views on the relevance of disability to dietitians.	Dietetic programs vary in their disability content. Research needed to better define disability-related competencies.

TABLE 2 (Continued)

Reference (Methodology)	Focus; Aim(s)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Data collection	Data analysis	Results reported	Conclusion
Chiavaroli et al, 2018 ²⁷	Competency assessment; To assess the knowledge, skills, capabilities, and professional judgement of overseas-educated dietitians against CS	Approach not stated; Validity evaluation using Messick's validity framework; IC	8 administrations of an MCQ exam over 5 years	Validity of the MCQ exam, relationships with other variables, stability of cut score, pass rates	52% candidates passed on the first attempt (most candidates from English-speaking countries passed on first attempt) Overall difficulty of the exam was relatively stable in terms of cut scores but pass rates varied by cohort Test reliability was mostly above 0.70.	The MCQ exam demonstrated acceptable reliability and validity
Palermo et al, 2018 ²⁵	Competence; To explore how dietetics students ready to graduate construct the concept of competence and the role of assessment in developing professional competence	Approach not stated; Qualitative description; IC	Focus groups	Inductive thematic analysis	Four themes: 1. No shared understanding of competence 2. Current placement experiences may not reflect current standards or workforce needs 3. Assessment approaches may not fully support competence development 4. The competence of workplace supervisors influences student constructions of competence	Need to develop alternative work placement experiences reflecting workforce needs. Practitioners should recognise their influence in shaping students' construction of competence.
Porter et al, 2019	Assessment; To review and moderate an assessment artefact of foodservice WIL to	Approach not stated; Portfolio artefact analysis; Some IC	Blinded moderation of WIL report by multiple assessors; focus group	Description of assessment outcomes, thematic analysis	Variation of assessment outcomes was evident. Three themes:	Inconsistency of outcome across multiple assessors highlights the need to rely on multiple assessments

(Continues)

TABLE 2 (Continued)

Reference (Methodology)	Focus; Aim(s)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Data collection	Data analysis	Results reported	Conclusion
	demonstrate competence				<ol style="list-style-type: none"> Importance of understanding the project scope Influences on assessment decision-making Importance of understanding broader assessment program 	and for shared understandings of competency expectations at practice entry.
Svarc et al, 2018 ³²	Practice (Placement) Education; To explore the impact of Aboriginal health placements on graduates' attitudes, confidence and preparedness to work in Aboriginal health	Approach not stated; Sequential mixed methods; Some IC	Survey, Semi-structured interviews	Descriptive and inferential statistics, content analysis	<p>Participants with Aboriginal placement experiences were more positive towards Aboriginal people/health, more confident and more likely to work Aboriginal focussed role</p> <ol style="list-style-type: none"> Situated learning experiences Breaking down stereotypes Empathy through learning from Aboriginal people Aboriginal health role models 	Aboriginal health placement experiences provide dietetic graduates with more positive attitudes and self-confidence working in Aboriginal health.
Twohig et al, 2019 ³⁵	Professional development education; To compare the characteristics of	Approach not stated; Case control study design; IC	Survey	Inferential statistics	Genomics trained group had higher mean knowledge, and	A relationship between training, knowledge, confidence and

TABLE 2 (Continued)

Reference (Methodology)	Focus; Aim(s)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Data collection	Data analysis	Results reported	Conclusion
	nutrition professionals who completed an online genomics course to those who completed an unrelated online course				confidence to perform 8 related activities than the untrained group. Both groups reported low implementation of nutritional genomics related activities in practice	involvement in nutritional genomics exists. Research needed to determine most effective methods for nutritional genomics education
Weber et al, 2019	Practice (placement) education; To evaluate the impact of a Clinical Educator model on the learning for students, preceptors and managers	Constructivist; Qualitative description; Some IC	Focus groups	Inductive thematic analysis	Four themes: 1. Clinical Educator improved time efficiency of placements 2. Clinical Educator facilitated student assessment within an assessment program 3. Clinical Educator was uniquely positioned to enhance student confidence 4. Clinical Educator improved capacity to manage underperforming and challenging student	Clinical Educator model increased student confidence, enhanced preceptors' capacity to manage underperforming students, facilitated assessment and reduced supervision burden.
Wilson et al, 2017	Professional development education; To explore the experience of dietitians participating	Approach not stated; Qualitative description; IC	Telephone interviews following 6 group mentoring sessions	Thematic analysis	Four themes: 1. Aboriginal health practice requires different ways of	The CoP is a useful approach for supporting dietitians

(Continues)

TABLE 2 (Continued)

Reference (Methodology)	Focus; Aim(s)	Philosophical Approach; Methods; Internal coherence (IC) (Yes/No/Some)	Data collection	Data analysis	Results reported	Conclusion
Yang et al, 2018	Curriculum; To investigate the empathy of dietetic interns	Approach not stated; Cross sectional survey; IC	Two validated surveys	Inferential statistics	knowing, being and working. 2. The CoP is a safe place to discuss, debrief and explore ideas. 3. Participation in the CoP contributed to workforce retention in Aboriginal health 4. Participation in the CoP contributed to dietitians improving their practice in Aboriginal health	working in Aboriginal health.

Abbreviations: CHAT, Cultural Historical Activity Theory; CARE, Consultation and Relational Empathy; CoP, Community of Practice; CS, Competency Standards; OSCE, objective structured clinical examination; TEQm, Toronto Empathy Questionnaire; WIL, work-integrated learning.

The authors do not make a clear case for their scientific approach and how it builds on existing understanding. Having two philosophical approaches (between their first and second aims) from the outset produces coherence issues as the researchers do not adequately consider, and explicitly report the considerations, from each approach at each step of their research. The authors' philosophy is not explicitly stated, which is a conventional feature of scientific approaches. However, given that the second aim was to understand student perspectives, philosophical transparency was required to achieve internal coherence. Indeed, this second aim aligns with qualitative methodology; however quantitative methods (in the form of a Likert scale) were chosen to understand these perspectives. Qualitative methods would have been more aligned (internally coherent) with understanding student perspectives. Supporting the researchers' presumed alignment with a scientific approach, their hypothesis is that placement performance is predicted by OSCE performance. Therefore, the research fails to consider alternative explanations for factors predicting placement performance, including other assessment tasks. Further, there is no acknowledgement of the complexity of the placement environment context that will almost certainly influence outcomes.³⁷

Taking an overt positivist or post-positivist philosophical approach that matches the scientific nature of this paper, the internal coherence of the study can be critiqued. The study's methodology, study design (retrospective cohort) and methods (observations measured as "grades" and Likert scale) analysed with one-way ANOVA are aligned with the scientific approach. These have been chosen by the researchers to objectively measure the relationship between OSCE and placement outcomes. However, there are assumptions made within this analysis which are neither explicit nor aligned with a purist scientific approach. Despite significant changes to the OSCE over the period of longitudinal data collection, the dependent variable (outcome) is largely treated as if it were unchanged across the years. Educational interventions are difficult to evaluate within a scientific paradigm for this reason, as well as the complexity of the settings in which they are administered.^{37,38} No reliability or validity measures of OCSE and placement outcomes were performed, representing further misalignment, resulting in unsubstantiated assumptions that these objective measures are "true" when in fact they are (we would argue) largely subjective. The researchers do not make explicit their values (axiology) but strongly imply a quest to find one single truth.

Considering the second stated aim of the research (student perceptions), the misalignment present is in the use of predefined statements with Likert scale responses

rather than qualitative methods, which would be better aligned with the aim. Likert scales are typically aligned with a scientific approach. The reported results confirm that the researchers have not fully explored students' perceptions, providing only the proportion of students agreeing with the researchers' predefined statements testing their hypothesis that the OSCE will predict placement performance.

Interpretive approach: Morgan et al³¹ took an *interpretive* approach exploring the experiences of, and challenges faced by, academic dietetics educators in preparing dietitians for the workforce. The study aim focuses on exploring experiences, challenges and perspectives based on past experiences (therefore privileging participants' subjectivities), making it clear that multiple realities are valued. The authors state that their study is underpinned by a social constructionist epistemology, and define this position. The methodology, labelled as "qualitative description", and methods, in-depth interviews, are closely aligned with the interpretive approach (so internally coherent). Data analysis, whereby meaning is constructed between participants' responses and researchers' interpretations, is made clear through the coding process. The results highlight the multiple stories and privilege context (in the study, university education and the cultural history of this) in data analysis. The discussion of results clearly highlight the complexity of the findings.

However, the introduction could more clearly highlight the need for an interpretive approach. While the authors reflexively describe their background and experiences, illustrating how those potentially influence their data interpretations, their motivations for doing so is to minimise bias (implying that dualism is key).³⁹ However, the minimisation of bias through dualism is privileged only in the scientific approach, rather than an interpretivist approach, which instead values the researcher-participant relationship in the co-construction of knowledge.¹⁴ How specifically the position of the researchers was managed or influenced data collection and analysis, and the development of knowledge (eg, how reflexive memos specifically managed this), could have been more clearly stated.

While the primary sampling approach involved maximum-variation sampling, aligned with gaining multiple perspectives, specifying a "random" approach within this sampling frame is misaligned with interpretive approaches. Indeed, aligned with the scientific approach seeking one universal truth, random sampling attempts to minimise bias and support generalisability.³⁹ Qualitative sampling however has a different purpose to quantitative sampling; instead trying to shed light on the particularities of phenomena.³⁹ Furthermore, using field notes for "validation" is again aligned with a scientific

approach (trying to find the “correct” interpretation), and inconsistent with quality markers in qualitative research.⁴⁰ The multiple perspectives are generally described as such, for example, using verbs such as “described”, “expressed” and “reflected”; however, occasionally through the results the authors present data as facts, for example, “some participants had unpleasant and uninspiring encounters” (p.385), which is inconsistent with the construction of understandings (as in “some participants reported...”). In their study limitations, the authors critique their study introducing terms like “validity” and “reliability”, which are terms aligned with the scientific approach. Their qualitative study is thus critiqued using scientific rather than interpretive quality markers. For example, they express avoiding desirability bias and leading during interviewing rather than embracing the subjectivity and co-construction of knowledge inherent in interpretive approaches (and inherent in their stated social constructionist approach). Indeed, it is highly problematic for researchers to critique studies with a stated philosophical position from an alternative standpoint. However, this appears to be somewhat common in published reports of qualitative research, either because researchers lack proper philosophical understandings of the different approaches, or because reviewers and editors lack such understandings, thereby mandating that researchers critique qualitative approaches from (preferred and known) scientific standpoints.

Critical approach: Taking a *critical inquiry* approach employing action research methodology and focus group methods, Palermo et al²⁴ critically reviewed factors relevant to recognition and promotion of excellence within the dietetics profession in order to facilitate change in Fellow credentialing. The researchers specifically stated their approach, enabling us to critique the paper for internal coherence. In the present study, positioning the problem of what constitutes excellence in the profession and how it is rewarded as an issue of power, structure and history clearly aligns the work with critical inquiry. Typically, critical approaches provide a voice to groups that are disempowered, presented in the present study as advanced practitioners. While this group may not be considered as marginalised or powerless typically; in the present study, the sample was presented as not having a voice. Specifically, the authors state that those not applying for Fellow had not previously had a voice in what constitutes excellence in the profession or how the Fellow credential was awarded. The authors' use of Cultural Historical Activity Theory⁴¹ is reasonably aligned with the critical approach in that it examines structural, cultural and historical factors influencing the social world, providing additional depth to their study findings.

The understanding of what constitutes excellence, a secondary aim of the study, is however more aligned with an interpretive approach, and identification of “factors” more aligned with a scientific approach, assuming these can be identified and measured. This misalignment also flows through to interview questions and the description of competency standards for Fellows, which departs from the mostly critical inquiry presented elsewhere. While the authors, being members of the profession and key stakeholders in the credentialing process, were aligned with a collectivist epistemology and espoused the need for change, there is limited description in the manuscript of the facilitation of change enabled through the research process. This highlights issues with axiology: the researchers clearly value making change but offer limited description in the paper about how change was enacted through the study. While critical approaches typically put participants at the centre of the research process, and indeed construct participants as co-researchers, the present study stated they achieved this through the researchers themselves being advanced practitioners-researchers. However, inconsistent with a typical critical inquiry approach, the focus group participants were not involved in the research design, or subsequent change processes hinted at. Engaging participants as co-researchers in the design and/or conduct of the research would have been more internally coherent with a critical approach.

4 | DISCUSSION

This manuscript has summarised scientific, interpretive and critical research approaches and described the importance of internal coherence between ontology, epistemology, axiology, methodology and methods for achieving research quality. Using an illustrative example for each of the scientific, interpretivist and critical approaches from dietetics education research, the importance of internal coherence has been demonstrated. Across the three manuscripts, all exhibited elements of internal coherence, in particular alignment between epistemology and methodology. However, each also demonstrated elements of misalignment, specifically between epistemology, axiology and method. Incoherence was typical where scientific principles were favoured despite the stated or implied philosophy. This highlights the profession's historical groundings privileging the scientific approach, showing how this can yield misalignment, particularly when describing the limitations of interpretive and critical inquiry approaches. The importance of internal coherence over and above existing quality assessment checklists for qualitative and quantitative methods must

be embraced into the future by researchers, peer reviewers and editors. The concept of internal coherence should be even considered as an additional quality marker, perhaps as an addition to existing quality checklists for all research designs.

The findings presented are consistent with calls in the medical education literature for the need to overtly articulate epistemological position to truly engage with the research outcomes.^{39,40,42} It is also consistent with other work demonstrating the dominance of the principles of scientific approaches being unthinkingly applied across other approaches,³⁹ and calls for internal coherence to be at the centre of quality judgements.²² It further supports narratives highlighting the limitations of checklists that do not support deep analysis of internal coherence in the review process. The present study also aligns with recent studies that outlines other key philosophical approaches to research. For example, in addition to interpretive, scientific and critical approaches, they also explore realism and socio-materiality.^{11,43–45} Within our search, there were no examples of these approaches, suggesting that papers published in *Nutrition and Dietetics* may be narrowly scoped in terms of philosophical approaches. Realist and socio-material approaches could be useful for nutrition and dietetics research. Realist approaches (such as realist syntheses and realist evaluation) have a scientific realism philosophy, which focuses on understandings of causality, often using mixed methods.⁴⁴ Socio-material approaches propose that the social and material worlds are connected and therefore explore the ways in which people and “things” interact.⁴⁵ Given the interaction between food and people, this epistemology has been proposed to assist understandings of complex problems of malnutrition.⁴⁶ What is not covered in this discussion is pragmatism, an approach also not returned in our search. Pragmatism focuses on experience and a continual process between beliefs and actions, embracing both singular and multiple realities/ontologies that aim to solve problems in real-world practice, often using mixed methods with a focus on the research questions rather than the methods.^{43,47} Skilled mixed methods researchers are able to effectively manage the conflict between opposing ontological and epistemological positions through careful attention to conceptualisation of both positions within the research problem.⁴⁸ While this is not an exhaustive list, it highlights the array of philosophies nutrition and dietetics researchers may consider, hopefully stimulating an appetite to read more.

The limitations of the present study include that the search limits possibly curbed the inclusion of relevant studies, as only manuscripts published in *Nutrition and Dietetics* and focused on dietetics education over the past few years were included. The inclusion of a critique of

the authors' own work (2 of 3 manuscripts) may be perceived as a biased selection by those viewing this paper from a scientific or positivist standpoint. One of these studies²⁴ was included as it was the only critical approach published in *Nutrition and Dietetics*; the other interpretivist example³¹ provided the best illustration of all potential interpretivist studies identified to demonstrate philosophical misalignment. This manuscript has summarised three prominent philosophical approaches to research and, through examples in dietetics education research highlighted the important role of internal coherence. What has not been presented is a synthesis of other philosophical approaches relevant to nutrition and dietetics research more broadly. The nutrition and dietetics research community may benefit from a more fulsome review of the extent to which internal coherence issues occur in practical nutrition and dietetics research.

The findings provide important implications for nutrition and dietetics research. Further consideration by researchers, peer reviewers and editors is needed on the importance of internal coherence. In addition, researchers working within any approach should ensure internal coherence between these elements in their research and should justify any areas of misalignment. Reviewers should avoid suggesting to authors that they revise their papers in a way that encourages misalignment, for example, criticising interpretive or critical inquiry research (often qualitative) for being self-reported, for bias, for lack of generalisability, or conversely, scientific approaches for lacking researcher reflexivity. Authors and reviewers must ensure an overt position is stated in research and that there is alignment between stated position and approach, rather than sole reliance on quality assessment checklists as a marker of quality.

In privileging scientific approaches to research, we cannot truly understand all complexities influencing nutrition in the social world. Classifying research as qualitative or quantitative does little to articulate the values or premises from which research is conducted and how knowledge is generated. The authors argue for consideration of epistemology at the outset of research, together with concerted efforts for ensuring internal coherence, as well as elements of rigour pertinent to research approaches such that nutrition and dietetics research makes a meaningful contribution to knowledge going forward.

CONFLICT OF INTEREST

Claire Palermo is Associate Editor and Dianne P. Reidlinger is Editor of *Nutrition & Dietetics*. 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.

AUTHORS' CONTRIBUTIONS

All authors conceptualised the study. Dianne P. Reidlinger completed the search and drafted the methods. All authors completed data analysis. Claire Palermo drafted the rest of the manuscript and Charlotte E. Rees and Dianne P. Reidlinger reviewed until all authors approved the final manuscript.

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SUPPORTING INFORMATION

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

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ORIGINAL RESEARCH

Statistical methods and software used in nutrition and dietetics research: A review of the published literature using text mining

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Abstract

Aim: Dietitians must be statistically literate to effectively interpret the scientific literature underpinning the discipline. Despite this, no study has been conducted that objectively identifies common statistical methods and packages specific to current nutrition and dietetics literature. This study aimed to identify statistical methods and software frequently used in nutrition and dietetics research.

Methods: A text mining approach using the bag-of-words method was applied to a random sample of articles obtained from all journals in the 'Nutrition and Dietetics' subject category within the SCImago Journal and Country Rank portal and published in 2018. A list of 229 statistical terms and 19 statistical software packages was developed to define the search terms to be mined. Statistical information from the methods section of included articles was extracted into Microsoft Excel (2016) for data cleaning. Statistical analyses were conducted in R (Version 3.6.0) and Microsoft Excel (2016).

Results: Seven hundred and fifty-seven journal articles were included. Numerical descriptive statistics were the most common statistical method group, appearing in 83.2% of articles (n = 630). This was followed by specific hypothesis tests (68.8%, n = 521), general hypothesis concepts (58.4%, n = 442), regression (44.4%, n = 336), and ANOVA (30.8%, n = 233). IBM SPSS statistics was the most common statistical software package, reported in 41.7% of included articles.

Conclusion: These findings provide useful information for educators to evaluate current statistics curricula and develop short courses for continuing education. They may also act as a starting point for dietitians to educate themselves on typical statistical methods they may encounter.

KEYWORDS

data mining, dietetics, education, evidence-based practice, nutritional sciences, statistics

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1 | INTRODUCTION

Research provides the evidence base that guides clinical practice. It informs decision making and ensures the delivery of optimal nutrition care to individuals and the broader community.^{1,2} In the context of nutrition, organisations such as the International Confederation of Dietetic Associations recognise the importance of research in International Competency Standards for Dietitian—Nutritionists, where evidence-based practice and application of research is a minimum requirement for entrance into the profession.³

To ensure evidence-based nutrition practice, ongoing consultation and critical appraisal of the literature is required.^{2,4} Research is fundamental to the application of nutrition science however involvement is inadequate among dietitians and nutritionists who primarily practise outside of research settings.^{5–7} Common barriers include a perceived lack of research methodology skills, as well as a lack of time, funding, and administrative support.^{7–10} Notwithstanding several efforts to address these obstacles,^{9,11,12} little improvement has been documented¹³ and few studies have sought to foster the development of specific research skills required for dietitians.

As statistical methods often underpin research outcomes,¹⁴ dietitians must be able to interpret and critique scientific data in any literature they are reviewing. Furthermore, those participating in higher-level research activities must understand statistics to successfully produce, analyse and disseminate findings of their own research.¹⁵ Despite this, not all Australian dietetics education programs include a named statistics subject, although some may include small elements in research theory content preceeding research project subjects.

A need for continuing education programs that focus on research skill development has been identified.¹⁰ For example, dietitians have expressed a desire to participate in relevant statistics courses beyond current entry-level requirements.^{6,13} Literature identifying statistical methods and software packages used in medical and public health research exists.^{14–16} However, no published study to date has reviewed those commonly used in nutrition and dietetics research literature.

This study aimed to identify statistical methods and software frequently used in current nutrition and dietetics research. It applied a modern technological approach in the form of text mining to derive information from a large collection of journal articles. This provides valuable, objective information to guide statistics curricula and continuing education for dietitians.

2 | METHODS

A text mining design based on the bag-of-words method¹⁷ was used to review the frequency of statistical methods and

packages reported in a random sample of nutrition-related journal articles published in 2018. This method counts the frequency of individual terms (unigrams) in a corpus (collection of text documents) by removing the structure of words and representing data as a multiset ('bag'), so that multiplicity is retained. The process of text mining here included the following steps: corpus selection, manual data extraction, generation of search terms, data cleaning and concatenation of search terms, quality assurance and statistical analysis to obtain results. As the study was restricted to published literature, ethical approval was not required.

All journals contained within the subject category of 'Nutrition and Dietetics' in SCImago Journal & Country Rank portal¹⁸ at the time of review (April 2019) were considered for inclusion. This portal provides an expansive list of discipline-specific papers as it contains all journals found in the Scopus database. To maximise generalisability across countries and subdisciplines of nutrition and dietetics, all journals within the subject category were eligible unless written in a language other than English or categorised as a book series.

For each journal, one issue published between January and December 2018 was randomly selected using the `RANDBETWEEN` function in Microsoft Excel (2016). All articles identified within each selected journal issue were manually reviewed by the primary researcher against the following inclusion criteria: (a) human subjects research, (b) available in full text, (c) full text written in English and (d) contained statistical analyses that were described within the methods section. All *in vitro*, cadaveric and animal model studies were excluded as they are not typically undertaken by dietitians in practice. Titles and abstracts were initially screened, and full texts of all potentially relevant articles were assessed to determine eligibility. Any queries were resolved by consensus with the research team (all authors).

As the aim of the study was to identify frequently used statistical methods, the sample size calculation was based on detecting words expressed in 50% of the sample. After obtaining all eligible articles, 748 were required to detect a proportion of 50% with a 2% error and a 95% confidence interval. To distribute this between the journals and prevent over-representation from any one journal, a maximum of 20 eligible articles were included from each journal. Articles were randomly selected using `RANDBETWEEN` when this limit was exceeded. All identified articles were managed in Microsoft Excel (2016) and included articles were imported into EndNote X8.

All included journal articles were saved as PDF files and converted into plain text files using Adobe Acrobat Pro DC (2017) to facilitate optical character recognition. Relevant data were manually extracted and entered in a Microsoft Excel (2016) spreadsheet article by one

researcher to create a central database where each row represented the data extracted from one journal article. To enhance the accuracy of identifying data of interest, only information that specifically described statistical analyses within the methods sections was extracted.

Text mining techniques were piloted in R (Version 3.6.0)¹⁹ by the primary researcher using 15% of the extracted data. As many statistical methods are multi-word terms or have various synonymous phrases, a framework containing a pre-specified list of unigrams was used to mine terms of interest. A list of statistical methods, which was developed using a Delphi panel to identify methods used in medical research was used as a starting point.¹⁴ The list was reviewed by all members of the research team. Modifications were made by a biostatistician with expertise in nutrition and dietetics to build on the list of synonyms and include statistical terms relating to meta-analyses. To capture multi-word terms and synonyms, each specific statistical method and its synonyms corresponded with a unigram that was created by concatenating the specific statistical methods. These unigrams were to be used to mine the terms of interest in the database. The final list included 229 statistical terms, which could be mapped to 16 statistical method groups, and 19 statistical packages. The framework of terms to be mined, including identified synonyms, is found in Supplementary File 1.

Data cleaning was performed in Microsoft Excel (2016). The 'find and replace' tool was used to tokenise multi-word statistical phrases to unigrams. All statistical methods that directly corresponded with the unigrams specified in the framework were concatenated (eg, Mann-Whitney *U* test became Mann-Whitney *U* test). Synonymous phrases were searched for (eg, Wilcoxon rank-sum test, another name for the Mann-Whitney *U* test) and replaced with the appropriate unigram (eg, Mann-Whitney *U* test). Misspellings were also corrected when encountered.

Once data cleaning was complete, a source data verification audit was conducted for assurance of data quality²⁰ and to identify any statistical terms of interest not yet contained in the framework. This involved the senior investigator conducting a manual verification check on a 10% random sample of the database against the original records. Error rate was less than 5%, all identified errors were amended, and the final database was saved as a csv file for analysis.

All statistical analyses were conducted by the primary researcher within R (Version 3.6.0) and Microsoft Excel (2016). Data were pre-processed in R using the 'tm', 'readr' and 'qdap' packages. Pre-processing involved transforming all text to lowercase, removing all numbers and punctuation, replacing multiple whitespace

characters with a single blank, removing English stop words and applying stemming algorithms to transform terms to their roots (eg, 'multilevelmodeling' and 'multilevelmodels' were reduced to 'multilevelmodel'). A further step to count the number of articles reporting statistical method groups was performed by replacing all specific statistical methods with the corresponding statistical method group. The pre-processed data were exported as Microsoft Excel files and the COUNTIF function was used to tally the total number of articles that reported each statistical method and statistical method group. To ensure only the exact words were counted, spaces were added before and after each unigram. A word cloud was produced using the 'wordcloud' package in R to visually present the most commonly reported inferential statistics within the corpus. The R codes to conduct the analyses are available in Supplementary File 2.

3 | RESULTS

A total of 124 journals were identified within the 'Nutrition and Dietetics' subject category of the SCImago Journal & Country Rank portal. Random selection of one issue within each eligible journal identified 2044 articles. Title and abstract screening removed 841 articles and 1203 full-text articles were assessed for eligibility. A total of 1085 articles were eligible. The final sample included 757 journal articles from 72 journals (Figure 1).

Twenty-three journals provided a large proportion of articles, together representing 49% of the corpus (Table 1). The majority of these 23 journals contributed 20 articles, as this was the upper limit per issue to prevent over-representation from any one journal. A large proportion (46.2%) of articles were published in journals that had a SCImago journal rank indicator within the first quartile, while 38.0% of articles were from journals in the second quartile, 12.8% in the third quartile and only 2.9% in the fourth quartile. The complete list of articles and their corresponding journals are found in Supplementary File 3.

The source data verification audit identified an error rate of 1.3%. This indicates a high level of data accuracy and falls within the acceptable limit of 5% or below, as set by Houston et al.²⁰

Numerical descriptive statistics were the most commonly used statistical method group and were reported in majority of articles (83.2%) (Table 2). The most frequently reported numerical descriptive statistic was mean (60.6%), followed by SD (37.1%) percent (23.2%), median (20.7%) and frequency (17.2%).

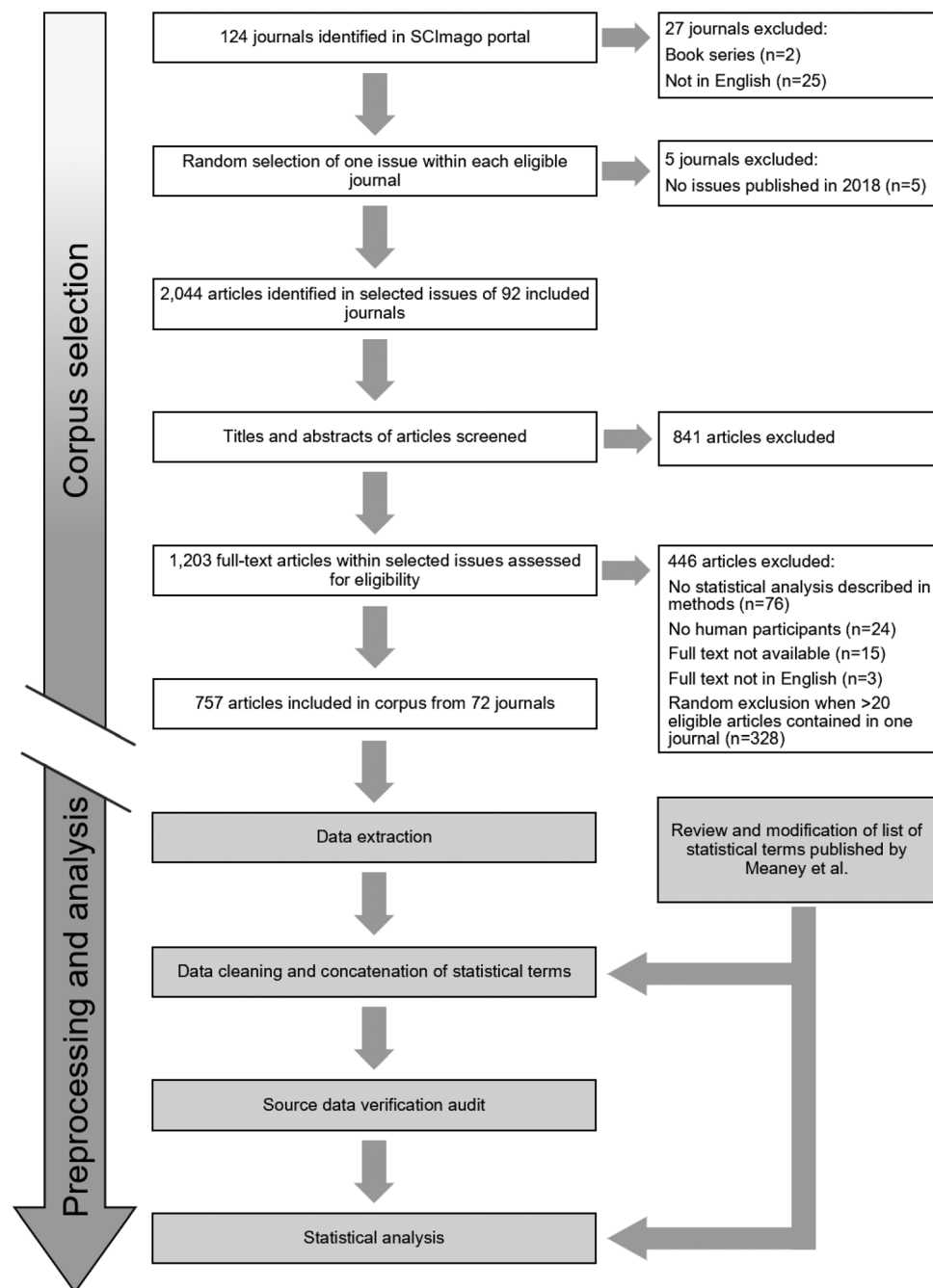


FIGURE 1 Flow chart of study procedures

Graphical descriptive statistics were not reported as often, appearing in 7.0% of articles. The second most frequently encountered statistical methods group was specific hypothesis tests, reported in 68.8% of articles. This was followed by general hypothesis tests (58.4%), regression models (44.4%) and ANOVA models (30.8%). Other common methods were epidemiological measures of risk and effect, epidemiological concepts of classification, and correlated data models, which appeared in 28.0%, 16.1% and 14.7% of articles, respectively. Within these groups were specific statistical methods and various terminology was found to be used by authors to describe individual methods (Table 3).

SPSS was cited as the most commonly utilised package and appeared in 41.7% of the reviewed articles (Table 2).

This was followed by SAS (17.2%) and STATA (15.9%). Other packages such as R and Microsoft Excel were less common, yet still used in 7.1% and 4.5% of articles, respectively (Table 2).

P-values (29.7%) and confidence intervals (24.3%) were the most commonly used measures of significance. The chi-square test was the most commonly reported hypothesis test (29.7%), followed by the independent samples *t*-test (22.3%), Mann-Whitney *U* test (15.1%), and the paired samples *t*-test (11.2%). Other common hypothesis tests included Pearson correlation, Spearman correlation, Shapiro-Wilk test for normality, Fisher's exact test, Kolmogorov-Smirnov test, Kruskal-Wallis test and the Wilcoxon signed-rank test. Nutrition professionals are also

TABLE 1 Characteristics of journals contributing $\geq 2\%$ of the corpus (n = 23/124)

Characteristics	SCImago journal ranking ^a	SCImago journal quartile ranking ^a	Count of articles (%)
<i>American Journal of Clinical Nutrition</i>	2	Q1	20 (2.64)
<i>International Journal of Obesity</i>	3	Q1	20 (2.64)
<i>International Journal of Behavioral Nutrition and Physical Activity</i>	4	Q1	20 (2.64)
<i>Clinical Nutrition</i>	10	Q1	20 (2.64)
<i>Journal of Clinical Lipidology</i>	14	Q1	20 (2.64)
<i>Maternal and Child Nutrition</i>	17	Q1	20 (2.64)
<i>Nutrients</i>	18	Q1	20 (2.64)
<i>Nutrition and Metabolism</i>	20	Q1	20 (2.64)
<i>Nutrition Journal</i>	25	Q1	20 (2.64)
<i>Appetite</i>	26	Q1	20 (2.64)
<i>Obesity Surgery</i>	28	Q1	20 (2.64)
<i>European Journal of Clinical Nutrition</i>	33	Q2	20 (2.64)
<i>Food Quality and Preference</i>	35	Q2	20 (2.64)
<i>Food and Nutrition Research</i>	48	Q2	20 (2.64)
<i>Journal of the International Society of Sports Nutrition</i>	50	Q2	20 (2.64)
<i>Asia Pacific Journal of Clinical Nutrition</i>	55	Q2	20 (2.64)
<i>Journal of Eating Disorders</i>	56	Q2	20 (2.64)
<i>Journal of Nutrition and Metabolism</i>	59	Q2	20 (2.64)
<i>European Journal of Nutrition</i>	27	Q1	19 (2.51)
<i>Clinical Nutrition ESPEN</i>	85	Q3	19 (2.51)
<i>Progress in Nutrition</i>	90	Q3	19 (2.51)
<i>Obesity</i>	9	Q1	16 (2.11)
<i>Nutrition</i>	31	Q1	16 (2.11)

^aJournal rankings were obtained from SCImago Journal & Country Rank portal in April 2019.

likely to frequently encounter the following ANOVA models: ANOVA (20.9%), RMANOVA (7.1%) and ANCOVA (6.6%), as well as logistic regression (20.2%) and linear regression models (15.9%). The most frequent epidemiological statistics were sensitivity (10.6%), odds ratio (10.2%) and prevalence (6.1%). Effect size was reported in 8.9% of the corpus. Multilevel models (8.5%) were the only advanced statistical model that appeared in more than 5% of the corpus. Inferential tests that were observed in 10 or more articles within the corpus are visually depicted in a word cloud (Figure 2). The complete counts of all statistical terms mined can be found in Supplementary File 4.

4 | DISCUSSION

Nutrition professionals require statistical literacy skills to effectively interpret the scientific literature that underpins

the discipline. This is the first study that comprehensively reviews the literature to identify statistical methods and packages commonly used in nutrition and dietetics research.

As hypothesised, numerical descriptive statistics were observed in most articles reviewed. This is in agreement with the findings of previous studies in other health-related disciplines,^{14,16,21} with some studies reporting their appearance in almost all articles. Our study also agrees with previous studies in medical research,¹⁴ where hypothesis tests, regression and ANOVA models were the most commonly reported types of inferential statistics.

Classical statistical techniques, such as the chi-square test and *t*-tests, appeared most frequently in the sample of articles. These methods are typically taught throughout introductory and intermediate statistics^{16,22} which indicates that they may be the most important for

TABLE 2 Frequency of articles reporting use of statistical methods groups and packages (n = 757)

	Count of articles (%)	Examples of common terms in each statistical method group
Statistical methods groups		
Numerical descriptive statistics	630 (83.2)	Mean, SD, percent
Hypothesis test (specific tests)	521 (68.8)	Chi-square test, <i>t</i> -tests
Hypothesis test (general concepts)	442 (58.4)	<i>P</i> -value, confidence interval
Regression	336 (44.4)	Logistic, linear regression
ANOVA	233 (30.8)	ANOVA, ANCOVA, RMANOVA
Epidemiology (risk estimation)	212 (28.0)	Odds ratio, effect size, prevalence
Epidemiology (classification and diagnostic accuracy)	122 (16.1)	Sensitivity, ROC curve, likelihood ratio
Correlated data analysis	111 (14.7)	Multilevel model, LMM, GEE
Missing data	62 (8.2)	Missing data, multiple imputation
Graphical descriptive statistics	53 (7.0)	Funnel plot, Q-Q plot, histogram
Multivariate statistics	37 (4.9)	Cronbach α , PCA, factor analysis
Survival analysis	34 (4.5)	Cox regression, Kaplan-Meier
Causal inference	20 (2.6)	Structural equation model
Computation	20 (2.6)	Bootstrap, resampling
Machine learning	17 (2.2)	Splines, discriminant analysis
Time series	3 (0.4)	Autocorrelation
Statistical packages		
SPSS	316 (41.7)	
SAS	130 (17.2)	
STATA	120 (15.9)	
R	54 (7.1)	
Microsoft Excel	34 (4.5)	
GraphPad	25 (3.3)	
Statistica	10 (1.3)	
Other ^a	31 (4.1)	

Abbreviations: ANCOVA, analysis of covariance; GEE, generalized estimating equations; LMM, linear mixed model; PCA, principal component analysis; RMANOVA, repeated-measures ANOVA; ROC, receiver operating characteristic; Q-Q plot, quantile-quantile plot.

^aOther software used in more than one article included RevMan (n = 7), Epidata (n = 6), GPower (n = 6), Systat (n = 4), MATLAB (n = 3), MINITAB (n = 3) and Python (n = 2).

nutrition researchers to understand, and most relevant for inclusion in dietetics education programs. An interesting finding related to the numerous variations in describing common inferential tests. It may be that the slight variation in terminology adds to the confusion of the reader. A finding from our research is that using recognised descriptions of statistical terms may be helpful, but also that researchers may need to be familiar with common synonyms used to refer to frequently used statistical methods (Table 3). Perhaps part of teaching statistics needs to be a recognition of the variation in 'labels' and that researchers can access simple lists of synonyms.

Despite the increased use of more complex statistical methods by researchers,^{14,15} it was surprising that a relatively low occurrence of advanced statistical techniques was observed. Multilevel modelling was the most frequently encountered advanced statistical method and only appeared in 8.5% of the articles. Similar findings were reported in a smaller study that investigated statistical methods used in public health research.¹⁶ The low occurrence of advanced methods could suggest their lack of importance or relevance in nutrition and dietetics literature, as many nutrition research questions can be answered using simple statistical techniques.²³ However, it has also been postulated that this may be due to the historic lack of training in these

TABLE 3 Common synonyms for frequently reported statistical methods in nutrition and dietetics research

Statistical method	Synonyms	Common Use
ANOVA models		
ANCOVA	Analysis of covariance	Comparing means of multiple groups while adjusting for covariates
ANOVA	Analysis of variance	Comparing means of multiple groups
RMANOVA	Repeated measures analysis of variance	Compare means of one or more variables at multiple time points
Correlated data analysis		
Multilevel model	Random effect model, random parameter model, random coefficient model, random intercept model, hierarchical linear model, hierarchical model, linear mixed-effects model, nested data model	Generally used for clustered or grouped data for example considering patients grouped/nested within a hospital
Intraclass correlation coefficient	Intraclass correlation coefficient	
Epidemiology (classification and diagnostic accuracy)		
ROC curve	Receiver operating characteristic curve	Visualising sensitivity and specificity
Relative risk	Risk ratio	Compares probabilities of outcomes in exposed and unexposed groups
Hypothesis tests		
Chi-square test	χ^2 test	Comparing proportions
Independent samples <i>t</i> -test	Independent <i>t</i> -test, Student's <i>t</i> -test, unpaired <i>t</i> -test, unpaired Student's <i>t</i> -test, independent measures <i>t</i> -test, independent two-sample <i>t</i> -test, two-sample <i>t</i> -test	Comparing two means - parametric
Mann-Whitney <i>U</i> test	Mann-Whitney Wilcoxon test, Wilcoxon rank-sum test, rank-sum test, Mann-Whitney nonparametric test	Comparing two means - nonparametric
Paired samples <i>t</i> -test	Paired <i>t</i> -test, dependent <i>t</i> -test, repeated measures <i>t</i> -test, paired Student's <i>t</i> -test, related <i>t</i> -test	Comparing means of two measures on the same subject/sample
Fisher's exact test	Fisher's test	Comparing proportions when there are low cell counts
Bonferroni correction	Bonferroni adjustment, Bonferroni post-hoc test, Bonferroni method	Adjusting for multiple comparisons
Tukey test	Tukey-Kramer test, Tukey's range test, Tukey's post-hoc test, Tukey's adjustment, Tukey correction, Tukey multiple comparison test, Tukey-Kramer adjustment, Tukey's HSD (honestly significant difference) test	Adjusting for multiple comparisons
Kruskal-Wallis test	Kruskal-Wallis H nonparametric test, Kruskal-Wallis H test, One-way ANOVA on ranks	Comparing means of multiple groups-nonparametric
Wilcoxon signed Rank Test	Signed rank test, Wilcoxon matched-pairs test, Wilcoxon matched-pairs signed-rank test	Comparing means of two measures on the same subject/sample—nonparametric
Egger's test	Egger's asymmetry test, Egger's regression test	Assessing publication bias in meta-analysis

(Continues)

TABLE 3 (Continued)

Statistical method	Synonyms	Common Use
Cohen's kappa	Cohens kappa, Cohen's k, kappa statistics, kappa correlation, κ kappa coefficient	Inter-rater reliability
Mantel-Haenszel test	Mantel-Haenszel χ^2 test, Cochran-Mantel-Haenszel test	Analysis of stratified 2 by 2 tables
Regression models		
Logistic regression	Logit regression, logit model	Predicting a binary outcome
Survival analysis		
Cox regression	Proportional hazards regression, Cox proportional hazards regression	Modelling variables predicting time to an event

Abbreviations: ANCOVA, analysis of covariance; RMANOVA, repeated-measures ANOVA; ROC, receiver operating characteristic.



FIGURE 2 A word cloud to provide a visual representation of the inferential tests most frequently observed in the corpus, where larger font sizes represent words that appeared more often than words with smaller font size

methods.¹⁶ Technological advances and the ready availability of open-source software packages such as ‘R’¹⁹ in the past 20 years have enabled researchers to apply advanced modelling and computationally intensive statistical methods to data analysis. Continuing education opportunities in advanced statistical methods such as these would ideally be available to assist and upskill nutrition researchers.

SPSS (IBM SPSS Statistics, IBM Corp., Armonk, NY), SAS (SAS Institute Inc., Cary, NJ) and STATA (STATA Corp., College Station, TX) were the three most prevalent statistical software packages. These packages have also been found to dominate the software used to conduct statistics within the public health literature.^{15,16} Therefore, exposure of students to at least one of these packages

through practical laboratory-based experiences in statistic courses would seem prudent for any introductory statistical training.

The overarching strength of this study is its innovative and computationally efficient text mining approach. This enabled a large sample of journal articles published in 2018 to be reviewed, providing a representative sample of current statistical methods used in nutrition and dietetics research not previously achieved. Despite this, the study had some limitations. Firstly, the extraction of statistical information from only the methods sections meant that information contained within other sections was not captured. While it is recommended that all applied statistical methods are described in a paper's methods, descriptive statistics are commonplace in results sections, particularly within figures. This may explain why the descriptive studies reported in our review were proportionately lower than other similar studies. As previous studies have reported descriptive statistics appearing in 95% or more of articles reviewed, it seems plausible that they may have also occurred in almost all articles within this review.

This study provides a representative overview however, its cross-sectional design is unable to establish any emerging trends over time. As trends towards increasingly complex statistical techniques have been observed elsewhere,¹⁴ it is important for nutrition researchers to be familiar with emergent methods. Follow-up studies or retrospective analysis to expand on our findings may provide further insight into any changed or emerging trends within the nutrition and dietetics literature.

While the use of a word cloud was an effective way to visually communicate commonly identified statistical methods, it is limited in its ability to uncover relationships. We are in agreement with previous studies that highlight the importance of considering how study design and methodology is associated with statistical techniques^{21,22} and future research may also consider collecting data on study design and methodology.

Lastly, readers should be aware of limitations relating to the text mining approach itself. One main disadvantage of text mining is the issue of polysemy (one word having multiple meanings) and synonymy (multiple words having the same meaning). Examples of polysemy within our database were single words such as 'average', 'power' and 'sensitivity'. These terms run the risk of their occurrence being overestimated as they may be used in a different context than statistical analysis. Best efforts were made to reduce this possibility by extracting only the information pertaining to statistical analysis within the methods sections. However, it is still possible these terms were used in a different context. Synonymy was also prevalent in the database, as authors used many variations in language to

describe a statistical method (Table 3). If not addressed, this may cause some statistical methods to be underrepresented. The generation of a framework was a notable strength of our study, as we were able to replace all corresponding phrases within a synonym set with a specific unigram that represented all phrases of the same statistical method. This significantly reduced the possibility of underestimating statistical methods, however, given the complexity of the English language, it is likely that not all possible synonyms were identified in the database.

In conclusion, this study presented an innovative text mining approach to identify the most frequently reported statistical methods in nutrition and dietetics research. These findings provide useful information for educators to evaluate current statistics curricula and develop short courses for continuing education. They may also act as a starting point for nutrition professionals to educate themselves on typical statistical methods they may encounter.

CONFLICT OF INTEREST

Marijka Batterham is Statistics Editor for Nutrition & Dietetics. 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. There are no further conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

MB initiated the project. AC conducted data collection, extraction, cleaning, and statistical analysis with guidance from MB and EB. MB modified list of searches terms and conducted quality assurance data audits. AC prepared the initial draft of the manuscript with input from MB and EB. All authors approved the final version of the manuscript.

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SUPPORTING INFORMATION

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

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