BMJ Open

Nutrition Competencies for Medicine: A Critical Synthesis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043066
Article Type:	Original research
Date Submitted by the Author:	29-Jul-2020
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Keywords:	MEDICAL EDUCATION & TRAINING, NUTRITION & DIETETICS, EDUCATION & TRAINING (see Medical Education & Training)

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Nutrition Competencies for Medicine: A Critical Synthesis

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Word Count (excluding title page, abstract, references, figures and tables): 3630

ABSTRACT

Background: Globally, 11 million deaths are attributable to suboptimal diet annually, and nutrition care has been shown to improve health outcomes. While medically trained clinicians are well-placed to provide nutrition care, medical education remains insufficient to support clinicians to deliver nutrition advice as part of routine clinical practice. Competency standards provide a framework for workforce development and a vehicle for aligning health priorities with the values of a profession. Albeit, there remains an urgent need to establish consensus on nutrition competencies for medicine. The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally.

Design: Integrative review.

Methods: CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched for published nutrition competency frameworks. This search was complemented by handsearching reference lists of literature deemed relevant. Data were extracted into summary tables and this matrix was then used to identify common themes and to compare and analyse the literature. Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review.

Findings: Using a pre-determined search strategy, 11 articles were identified. Five common themes were identified and include 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based.

Conclusions: This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Keywords: Competency-based education, Medical education, Nutrition competencies, Nutrition education

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This review offers a critical and timely synthesis of medical nutrition competencies and a conceptual nutrition competency framework.
- Themes such as communication and team work are not specific to nutrition and highlight integration of topics across a curriculum.
- As an integrative review, this framework might be considered a candidate theory for further review and development.
- It is recognized that the characteristics of included publications is skewed towards those published in the USA and that there may be other frameworks internationally. However, it is relevant to note that there are a greater number of medical education facilities in the USA than other countries included such as Australia, New Zealand and Sweden (1).
- The dynamic nature of competency-based research, and subsequent differences in competency frameworks included may also be considered a limitation.

INTRODUCTION

Globally, 11 million deaths are attributable to suboptimal diet annually (2). Nutrition is a powerful tool for the prevention and management of diet-related chronic diseases (2). Nutrition care refers to any intervention performed by a health professional to improve the nutrition behaviour and subsequent health status of an individual or community, and has been shown to improve diet-related and health outcomes, often with reduced risk, side effects and costs when compared with pharmacological interventions (3, 4). For example, when doctors provide nutrition advice as part of prenatal care, their patients have fewer complications associated with pregnancy and give birth to healthier children (5). In fact, a recent systematic analysis reports that improvement of diet could potentially prevent one in every five deaths globally (2). Furthermore, public health legislation such as the Patient Protection and Affordable Care Act recognise the increased need for preventive healthcare interventions, such as nutrition care (6). Therefore, it is essential that clinicians of all backgrounds are cognizant of the role of nutrition in health and are well-equipped to initiate and support nutrition care as part of routine clinical practice.

Medically trained clinicians are well-placed to initiate and support patient nutrition care (7), in part due to their regular contact with the individuals for whom they provide care (8). Despite this, a recent systematic review indicates that medical education remains insufficient to support clinicians to provide nutrition care as part of routine clinical practice (9). Competency standards provide a framework for workforce development and are essential for the delivery of safe, effective and patient-centred care (10) and a vehicle for aligning the health priorities of the country with the values of a profession (11). This is particularly relevant, as there is an existing disconnect between medical education and the exigent double burden of malnutrition (9). While there are many approaches to developing a competency framework, authors argue that a preoccupation with discipline-specific tasks overlooks the relevance of cross-cutting attributes such as critical thinking, communication and collaboration which align outcomes across disciplines (10, 12). An integrated approach to competency encompasses the ability to combine and apply practical and reflexive competence in different contexts (12). The use of competency standards in improving medical nutrition education has been previously established (13) and has been shown to increase a clinician's ability to integrate nutrition into patient care (4). Competency in nutrition care is important in the delivery of safe, effective and co-ordinated care (14). However, there is a recognised need to establish consensus on relevant

nutrition competencies for medicine (9). The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally. As the UN *Decade of Action on Nutrition 2016-2025* is well underway, this is a timely and important review (13).

METHODS

This review was an integrative literature review, a "form of research that reviews, critiques and synthesises representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" (15). This methodology is considered rigorous in this context (16, 17). Data were extracted into summary tables (16) and this matrix was then used to identify common themes and compare, contrast and analyse the literature (18). Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review (19-21).

For the purposes of this review, we initially defined key concepts based on published definitions and author experience (Table 1).

Table 1. Definitions of key concepts used within this review

Concept	Definition
Competency (or competency standard)	A measure used to describe the idealized capacity of an individual to perform a role or set of tasks (22).
Competence	Competence can be described as the ability to perform a task with desirable outcomes under varied circumstances. This definition encompasses multiple components such as the habitual and judicious application of knowledge, technical skills, values, clinical reasoning and attitudes (23, 24).
Domains of competence	Competency domains represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (25).
Competency framework	A competency framework represents a complete collection of competencies required for effective performance (10).
Curriculum framework	A curriculum framework is an organised set of standards or learning objectives that define educational requirements

Search methods

CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched for published nutrition competency frameworks by adapting the Search Strategy in Appendix 1. In brief, the key concepts were related to medically trained clinicians, nutrition and diet and competency. A research team comprised of all authors in this study, as well as a medical librarian, agreed upon terms with the aim of avoiding researcher bias when selecting articles. This search was complemented by handsearching reference lists of literature deemed relevant.

Inclusion criteria for this review were original research publications representing nutrition competencies for the continuum of medical education, from undergraduate medicine through to practice. Interdisciplinary nutrition competency frameworks were included if the framework stipulated use by the medical profession. Frameworks which included elements of nutrition, but which are not nutrition-specific, were excluded for the purpose of this review. Frameworks which included nutrition competencies but are specific to a disease, condition or specialty (e.g. nutrition competencies for cardiovascular disease) of the medical profession were also excluded. While these frameworks may inform discussion related to the integration of nutrition in medical competency frameworks, the aim was to review nutrition competencies to inform the development of a nutrition competency framework for the broad medical workforce in the first instance. Where an updated version of a framework existed, we excluded previous versions of the framework. Editorials, reviews, conference proceedings, opinion papers and interviews were also excluded. The results of the search were not limited by time or language.

Search outcome

All database searches were directly imported into the electronic reference management tool Endnote© Version X9 (Clarivate Analytics, Philadelphia, USA) and grey literature searches were manually entered by the primary author (BL). After the removal of duplicates using EndNote and manually, one author (BL) independently screened titles and abstracts and selected studies according to the pre-defined inclusion criteria. If the abstract was not sufficient, full-texts of remaining papers were screened independently to identify publications for inclusion. Where it was not clear, the primary author engaged in consultative and iterative discussion amongst authors in order to reach consensus. All authors reached consensus on the included articles.

Data analysis

Data extraction was completed independently by the primary researcher (BL). Information relating to nutrition competencies was extracted from the retained articles. Information discussing the nutrition-related knowledge, skills or attitudes which published authors believed medical practitioners needed to obtain was categorised as a competency and recorded. Similarly, competency domains or themes represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (25). Information related to competency domains was also included. Data was extracted from each paper into a summary table and series of matrices. The following information was extracted from full-text publications and presented systematically: citation and country, organisation/group, name of the framework, nutrition domains (if stated), nutrition competencies, learning objectives (if stated) and the level of medical education that the framework is intended for (e.g. residency). Findings were read, re-read and articles compared and contrasted to identify patterns and relationships.

Quality appraisal

To determine quality and risk of bias for review, the full text of each article was assessed independently for quality (including risk of bias) by the primary researcher (BL). Given the variation in research methodologies, the Critical Appraisal Skills Programme (CASP) tool was modified for use, as adapted by Halcomb et al. (2016) (CASP, 2019; Halcomb et al., 2016).

Patient and Public Involvement

There is no patient and public involved in the study.

RESULTS

Search results

The total yield from all databases was 19,709 results. This was reduced to 14,023 results after the removal of duplicates, of which there were many. Using the exclusion criteria against title

and abstract, a total of 56 full-text publications were assessed for eligibility, including four publications identified through hand searching of reference lists (Figure 1). It is of interest to note that a considerable number of results were related to the impact of a nutrition course or competency framework on nutrition knowledge, skills and attitudes and therefore not eligible for inclusion. Following full-text review, 11 articles were included in the review. Reasons for exclusion included papers which did not include competencies or a framework (n=18) and competencies that are not specific to nutrition or competencies for a specific aspect of nutrition or health care (for example cardiovascular disease nutrition competencies) (n=15).

Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

Characteristics of included publications

Included studies were published between 1983 and 2019. The majority were peer-reviewed articles (n=7), with the remaining grey literature comprising of documented frameworks form expert professional groups (for example, professional associations or accrediting bodies) (n=3) and a position statement (n=1). Seven studies were from the USA, with one study from each of Australia and New Zealand, Africa, Sweden and the UK.

Quality appraisal

Descriptions of how the competency frameworks were developed varied in level of detail. It is important to note that few publications reported the research methods used to develop their frameworks. Furthermore, few publications acknowledged the limitations or weaknesses of the processes used to develop the competency frameworks. Given these limitations, articles that did not achieve a 'yes' on all items of the checklist were not excluded from the review, but the appraisal was taken into consideration in the overall rigour of the present review (Table 2).

Table 2. Quality appraisal

1. Was the research design appropriate to address the aims of the research?
2. Was the data collected in a way that addressed the research issue?
3. Was the data analysis sufficiently rigorous?
4. Is there a clear statement of the study findings?
5. Are there limitations or weaknesses of the study acknowledged?
6. Is the research valuable?

	Q1	Q2	Q3	Q4	Q5	Q6
American Academy of Family Physicians, 1998	Unclear			Yes	No	Yes
Asp et al., 1995	Unclear					Yes
Cuerda et al., 2019	Yes	Yes	Unclear	Yes	No	Yes
Deen, Karp & Lowell, 1994	Unclear			Yes	No	Yes
Deakin University Strategic Teaching and Learning Grant Steering Committee, 2016	Yes	Yes	Unclear		No	Yes

Jhpiego & Save the Children, 2012	Yes	Yes	Yes	Yes	No	Yes
Lindsley et al., 2017	Yes	Yes	Yes	Yes	No	Yes
Maillet & Young, 1998	Unclear			Yes	No	Yes
Sierpina et al., 2016	Unclear				Yes	Yes
Young et al., 1983	Yes	Yes	Yes	Yes	Yes	Yes
ICGN Undergraduate Nutrition Education Implementation Group, 2013	Unclear					Yes

Competency domains

Five of eleven publications (45%) explicitly used competency domains to categorise or sub-divide nutrition competencies. Different methods of classification, or domains, included type of competency (such as knowledge, skills and attitudes), domains of human nutrition (including concepts of basic nutrition, concepts of applied nutrition and principles of clinical nutrition) and sub-division of competencies by nutrition concept (for example, macronutrients and micronutrients) or by elements of nutrition care (for example, diagnosis, treatment, prevention) (26-31). The most common competency domains were related to the role of nutrition in health promotion and disease prevention (n=3), nutrition assessment (n=2) and nutrition management (n=2) (27, 28, 30). Competency domains which were identified but only found within one framework included those related to patient nutrition counselling skills, nutrition referral, nutrition evidence, aspects of critical nutrition care (such as enteral and parenteral nutrition) and the impact of disease on nutrition (27, 30).

The Nutrition Competency Framework (NCF) for medical graduates, developed by the Deakin University Strategic Teaching and Learning Grant Steering Committee in Australia, was the only framework in this review purposefully mapped to a medical framework, namely, the Australian Medical Council (AMC) Graduate Outcome Statements (29, 32). Other frameworks in this review, published in the United Kingdom, are endorsed by statutory bodies such as the General Medical Council (GMC) and Medical Schools Council (30, 33, 34). Some inter-disciplinary nutrition competency frameworks also delineated competencies, such as by amount of patient education responsibility or by level of service delivery, to emphasise the relevance of nutrition competencies for the wider health workforce (35, 36).

It is clear that despite differences in the taxonomy and language across included nutrition competencies for medical education, there are some common underlying themes, which in some contexts may be considered "domains" if the papers are summarised. Specifically, five common themes were identified across the included nutrition competencies, including clinical practice (all 11 publications), health promotion and disease prevention (n =8), communication (n=7), working as a team (n=7) and professional practice (n=3). These themes overlap with existing medical competency standards and could be considered cross-cutting.

Competencies

Twenty-five unique nutrition competencies for medical education were identified in the 11 publications. Fifteen of twenty-five nutrition competencies for medicine were classified as knowledge/behaviour-based competencies. For example, 'Demonstrate knowledge of the functions of essential nutrients' (27, 31). Seven nutrition competencies were classified as skill-based (for example, 'Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease' (27, 29-31, 35-39)) and only four competencies were attitude/value-based (for example, 'Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status' (27) (Table 4). The most common nutrition competencies (suggested in greater than 50% of articles), were related to 1) skills in nutrition assessment, 2) the ability to prescribe dietary interventions in the prevention and treatment of disease, 3) knowledge of the role of nutrition in health promotion and disease prevention and 4) knowledge of the social and cultural importance of food, including food consumption trends and current nutrition recommendations. Authors less commonly suggested the relevance of demonstrating competency in how disease can affect nutritional status, food-borne illness, an awareness of personal health and nutrition and a commitment to provide evidence-based nutrition care for all patients regardless of health status. Articles published in developed countries were more likely to recommend competencies related to nutritional management of chronic diseases, while studies originating from developing countries included competencies related to emergency medicine and nutritional management for people living with HIV and AIDS (27, 36). One paper specified cross-cutting nutrition competencies for all health professionals including community mobilisation and nutrition counselling (36).

Table 3. Nutrition competencies for medicine

Theme and number of publications which include this theme	Domain	Competency	Competency Type	n[a]
Clinical Practice n=11 (100%)	Nutrition Assessment	Demonstrate skills in the assessment of nutritional health including the ability to calculate energy expenditure, nutrition requirements and body composition (14, 26, 27, 29-31, 35-39)	Skill	11
	Nutrition management	Demonstrate knowledge of evidence-based dietary strategies for prevention and treatment of disease (14, 26, 27, 29)	Knowledge/Behaviour	4
		Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease (27, 29-31, 35-39)	Skill	9
		Demonstrate knowledge of possible drug-nutrient interactions and prescribe accordingly (14, 26, 27, 31, 37)	Skill	5
		Demonstrate knowledge of breastfeeding and complementary feeding practices (27, 36)	Knowledge/Behaviour	2
	Nutrition monitoring and evaluation	Demonstrate the ability to monitor nutrition status and modify dietary recommendations as needed (37, 38)	Skill	2
Health promotion and disease prevention n=8 (73%)	Basic sciences as applied to nutrition	Demonstrate knowledge of the basic scientific principles of human nutrition (26, 27, 29)	Knowledge/Behaviour	3
		Demonstrate knowledge of nutrition applied to different stages of the life cycle (26, 27, 31)	Knowledge/Behaviour	3
		Demonstrate awareness of the nutritional content of food including the major dietary sources of macronutrients and micronutrients (26, 27, 31)	Knowledge/Behaviour	3
		Demonstrate knowledge of the difference between food allergies and food intolerance (26, 27, 31)	Knowledge/Behaviour	3
		Demonstrate knowledge of the functions of essential nutrients (27, 31)	Knowledge/Behaviour	2

		Demonstrate an understanding of how disease and its management can affect nutritional status (30)	Knowledge/Behaviour	1
	The role of nutrition in health promotion and disease prevention	Demonstrate an awareness of their own personal health and nutrition (14)	Attitude/Value	1
		Demonstrate knowledge of the role of nutrition in health promotion and disease prevention (26, 27, 29-31, 35, 39)	Knowledge/Behaviour	7
		Demonstrate knowledge of the social and cultural importance of food, including awareness of food consumption trends and current nutrition recommendations (14, 26, 27, 29, 31, 39)	Knowledge/Behaviour	6
		Demonstrate knowledge of nutrition-related causes of mortality and morbidity in the population (14, 26, 39)	Knowledge/Behaviour	3
		Demonstrate knowledge of the principles of public health nutrition, including strategies to reduce the burden of disease (27, 36)	Knowledge/Behaviour	2
		Describe food-borne illnesses and outline the process of reporting and investigating outbreaks of these illnesses (27)	Knowledge/Behaviour	1
Communication n=7 (64%)	Nutrition counselling skills	Demonstrate the ability to effectively provide nutrition education and counselling (14, 26, 27, 31, 35, 38)	Skill	6
		Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status (27)	Attitude/Value	2
Working as a team n=7 (64%)	The Multidisciplinary Team Approach to nutrition care	Demonstrate the ability to work effectively in a multidisciplinary team to deliver nutrition care, including the ability to refer onwards (14, 27, 29, 35, 37)	Skill	5
		Demonstrate knowledge of the role of other health professionals and community services in the multidisciplinary approach to nutrition care (27, 31, 39)	Knowledge/Behaviour	3
Professional Practice n=3 (27%)	Critical thinking	Demonstrate ability to think critically including the ability to interpret nutrition evidence and apply appropriately in clinical practice (14, 27, 29, 31, 38)	Skill	3
	Ethics	Demonstrate the ability to consider and apply principles of ethics related to nutritional management (26, 27, 29)	Attitude/Value	2

		Demonstrate a commitment to promote sound nutritional decision-making and appropriate levels of physical activity for all patients regardless of health status (27)	Attitude/Value	1

[a]**Number of articles which include this competency**

Level of medical education:

All 11 articles specified the level of medical education where there would be an expectation to teach and achieve the nutrition competencies. Five articles included nutrition competencies for undergraduate and graduate (entry-level) medical education. Three of the 11 articles stipulated use by primary care providers and one paper included competencies for family practice residents. The remaining two articles merely specified use by "practicing physicians".

Summary of concepts

A summary competency framework adapted from Hughes et al. (2012) (12) and informed by the Dreyfus model of skill acquisition, the framework for clinical competency assessment outlined in Miller (1990) and the Knowledge to Action Cycle as described by Graham and colleagues (2006) (12, 19, 20, 40, 41) is presented based on the competencies in the literature (Figure 2). This provides a preliminary model for a nutrition competency framework for medicine, which can be further investigated in subsequent research. In this framework, categories of competency units are delineated into four different tiers to represent hierarchies of competency acquisition and assessment. At the base of the matrix are enabling and critical competencies (know and know how) which underpin higher level nutrition practice behaviours. At a foundational level, the Dunning-Kruger Effect indicates that individuals may be 'unconsciously unskilled' (42). The proposed framework also includes common, cross-cutting attributes identified in this review. Cross-cutting competencies delineate the professionalism required for effective, collaborative and safe practice and improve the transferability of the competency framework across health disciplines (12). Top-level practice competencies are defined by Hughes et al. (2012) as "higher order composite behaviours" which are required to "perform complex practice behaviours" which underpin core functions of the profession (12). Practice competencies involve behavioural performance (showing how and doing) and it is hoped the inclusion of these competencies bridges the gap between cognitive competencies and translation in practice (12).

Figure 2. Proposed conceptual nutrition competency framework for medicine

DISCUSSION

There is currently no consensus on nutrition competencies relevant for medical education. This review provides a critical synthesis of published nutrition competencies for medical education and practice internationally. This review identified five common themes across nutrition competencies which add to existing literature related to medical nutrition education. Twenty-five unique nutrition competencies for medical education were identified from 11 articles.

The five common themes across nutrition competencies for medicine, were clinical practice, health promotion and disease prevention, communication, working as a team and professional practice. The latter three, while referring to nutrition, highlighting generic skills that are required to be applied across all aspects of medical care. This is congruent with core competencies and individual roles in existing medical frameworks, such as the CanMEDS Physician Competency Framework, the Accreditation Council for Graduate Medical Education (ACGME) core competencies, the General Medical Council (GMC) Outcomes for graduates, the Australian Medical Council Limited (AMC) Graduate Outcome Statements and the Royal Australasian College of Physicians (RACP) Professional Practice Framework (32, 43-46). For example, the CanMEDS Physician Competency Framework, one of the most globally recognized health care profession competency frameworks articulates a number of intrinsic roles which reflect key themes identified in this review, such as the Communicator, Collaborator and Health Advocate.

Generic themes such as those identified in this review can provide leverage in educational reform, by aligning incentives to facilitate synergy across health care professions (47). For example, a multidisciplinary team (MDT – identified as "working as a team" in this review) approach to nutrition care has been shown to provide high quality, cost-effective nutrition outcomes (48, 49). However, there is a disconnect between the university education environment, which is generally not interdisciplinary, and the practice environment, which increasingly requires collaborative skills (47). Furthermore, communication and collaboration are key aspects of the iterative process of knowledge translation, including the ability to exchange information to overcome barriers to implementation. Communication and collaboration (teamwork) were also common themes identified by this review. Optimized knowledge translation has been shown to improve the quality of evidence-based nutrition care and strengthen the health care system, as summarised by the Knowledge to Action Cycle (41).

Not only does this cross-over between medical and nutrition competencies highlight the lateral nature of nutrition as a cognate scientific discipline, it provides merit to opportunity for the vertical integration of nutrition competencies into existing medical education. Rather than an isolated concept with a distinct set of competencies, existing medical spiral curricula could be enhanced by applying existing medical competencies to a nutrition context. Deen (2006) illustrated this by successfully mapping the Curriculum Committee of the National Academic Award (NAA) learning objectives to the ACGME competencies for competency-based resident evaluation (50). This reiterates the relevance of nutrition as a core facet of clinical practice without necessarily adding time to curricula. Namely, vertical integration of nutrition competencies into medical education is particularly relevant in a crowded curriculum, and is a key element of a successful integrated medical nutrition curriculum, shown to improve medical students' perceptions of nutrition as part of total patient care (51, 52).

The majority of the medical nutrition competencies identified in this review were knowledge-based, while less than 30% of nutrition competencies were skill-based and only four competencies were attitude-based (Table 3). While knowledge-based (enabling) competencies are essential to interpret new concepts in nutrition and underpin higher order (practice) competencies, skill-based competencies are relevant to clinical practice, which requires the complex and judicial application of knowledge, technical skills, clinical reasoning, values and reflection under varied circumstances (24). This is in line with the experience of medical graduates and practising physicians, who do not feel comfortable or adequately prepared to provide nutrition counselling to their patients (7, 9, 53, 54). In order to overcome these barriers, Adams et al., (2010) and Lindsley et al., (2017) emphasise the need for "skill-centred nutrition training" (55). A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals, reports that educational interventions which led to improvements in the delivery of nutrition care focused on skills and attitudes rather than just knowledge (56). Skill-based nutrition training has been shown to improve medical students' nutrition knowledge and confidence in lifestyle counselling (57).

Earlier research highlights the effectiveness of the Objective Structured Clinical Exam (OSCE) in evaluating the ability to synthesise and translate knowledge to clinical practice (52). Miller (1990) also emphasises the role of skill-based assessment methods such as the OSCE in the appraisal of technical and clinical competence. Problem-based learning tutorials, culinary skills

training and clinical case presentations have also been shown to promote active learning and lead to significant changes in participants' knowledge, personal health habits, confidence to provide dietary counselling and ability to nutritionally manage malnutrition (56). A combination of innovative learning strategies is required to support the development of clinical competence. Educational strategies and assessment methods which improve nutrition care competencies, such as problem-based learning and the OSCE, are already widely used methods in medical education (58). Therefore, the application of existing learning to a nutrition context, such as a nutrition OSCE, may lead to improvements in competency to provide nutrition care in future practice. The nutrition competencies identified in this review provide a potential benchmark for the nutrition knowledge, skills and attitudes to be included in curricula (Table 3).

While vertical integration is not a new recommendation (59), there is little existing guidance on how to do this. Furthermore, while competency frameworks provide an architectural blueprint for constructing educational programmes, the centrality of valid assessment methods to support the life-long journey of competency development cannot be overlooked (11). Increasing the weighting of a topic in assessment has been shown to enhance medical students' reported motivation to learn about the topic (60). Furthermore, regular and repeated assessment can improve knowledge retention in medical students (61, 62). This is particularly important given that despite initial high interest in nutrition, interest in and perception of the importance of nutrition may decline during time in medical school (63).

CONCLUSION

This review identified five common, cross-cutting themes across nutrition competencies for medicine: 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based. The most common nutrition competencies were related to nutrition assessment, dietary interventions for the prevention and treatment of disease, the role of nutrition in health promotion and disease prevention and knowledge of the social and cultural importance of food. This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Acknowledgements: We would like to thank Isla Kuhn, Medical Librarian at the University of Cambridge for her invaluable input to the search strategy.

Contributors: BL, EB, KM and SR contributed to the design of the review. BL did the literature search, performed data analysis and drafted the manuscript. EB contributed to data extraction. All authors contributed to revision of the manuscript and approval of the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Patients and/or the public were not involved in this study.

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests: None declared.

Patient consent for publication: Not required

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Appendix 1 – Scopus search strategy (adapted for use on other databases)

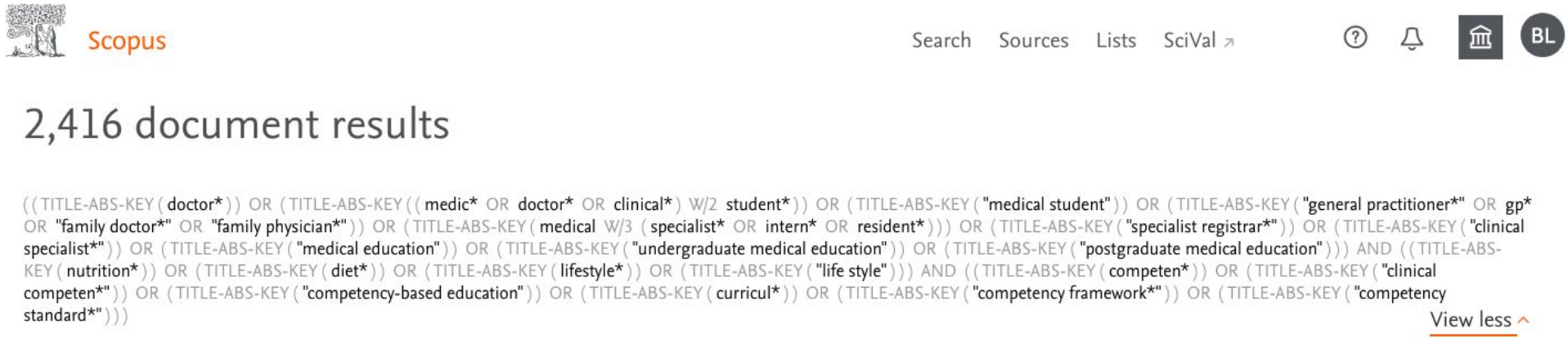


Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

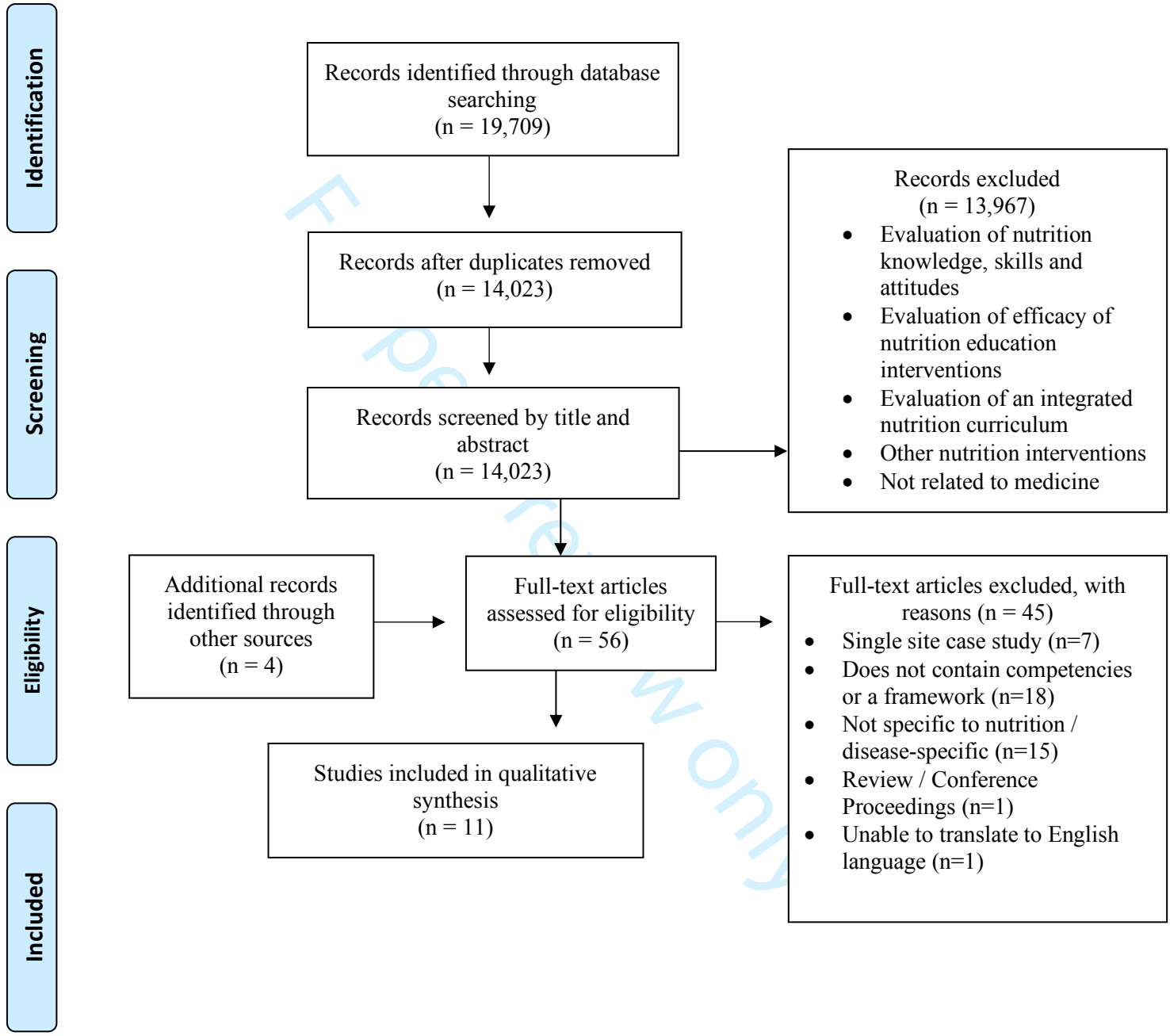
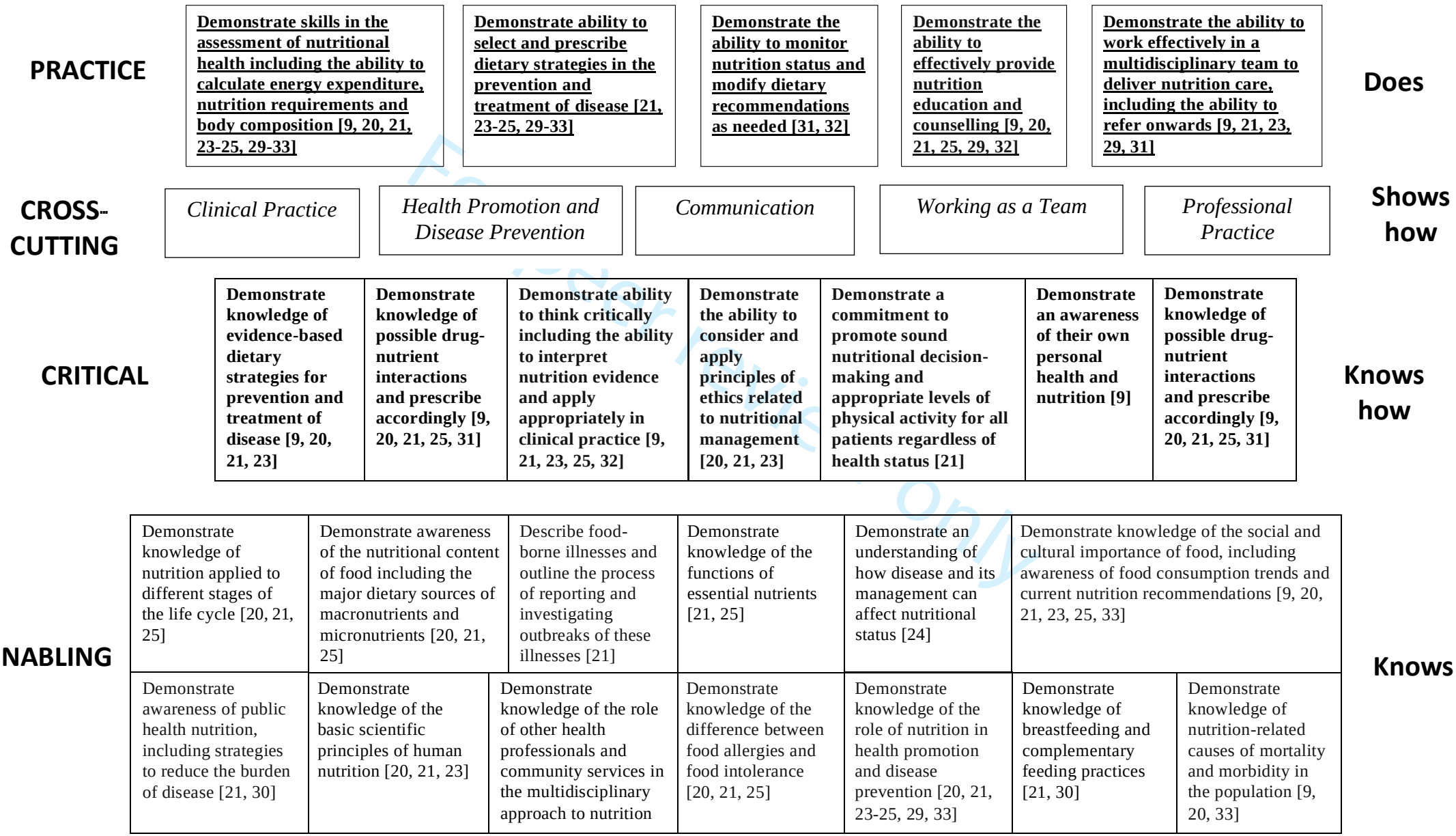


Figure 2. Proposed conceptual nutrition competency framework for medicine



BMJ Open

Nutrition Competencies for Medicine: An Integrative Review and Critical Synthesis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043066.R1
Article Type:	Original research
Date Submitted by the Author:	18-Dec-2020
Complete List of Authors:	Lepre, Breanna; University of Wollongong, School of Medicine; NNEdPro Global Centre for Nutrition and Health, Mansfield, Kylie; University of Wollongong, School of Medicine, University of Wollongong, and Illawarra Health & Medical Research Institute Ray, Sumantra; NNEdPro Global Centre for Nutrition and Health, St. John's Innovation Centre Beck, Eleanor; University of Wollongong, School of Medicine, University of Wollongong and Illawarra Health & Medical Research Institute
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MEDICAL EDUCATION & TRAINING, NUTRITION & DIETETICS, EDUCATION & TRAINING (see Medical Education & Training)

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Nutrition Competencies for Medicine: An Integrative Review and Critical Synthesis

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Word Count (excluding title page, abstract, references, figures and tables): 4000

ABSTRACT

Objective: Globally, 11 million deaths are attributable to suboptimal diet annually, and nutrition care has been shown to improve health outcomes. While medically trained clinicians are well-placed to provide nutrition care, medical education remains insufficient to support clinicians to deliver nutrition advice as part of routine clinical practice. Competency standards provide a framework for workforce development and a vehicle for aligning health priorities with the values of a profession. Albeit, there remains an urgent need to establish consensus on nutrition competencies for medicine. The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally.

Design: Integrative review.

Data sources: CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched through April 2020.

Eligibility criteria: We included published nutrition competency frameworks. This search was complemented by handsearching reference lists of literature deemed relevant.

Data extraction and synthesis: Data were extracted into summary tables and this matrix was then used to identify common themes and to compare and analyse the literature. Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review.

Results: Using a pre-determined search strategy, 11 articles were identified. Five common themes were identified and include 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based.

Conclusions: This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Keywords: Competency-based education, Medical education, Nutrition competencies, Nutrition education

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This review offers a critical and timely synthesis of medical nutrition competencies and a conceptual nutrition competency framework.
- Themes such as communication and teamwork are not specific to nutrition and highlight integration of topics across a curriculum.
- As an integrative review, this framework might be considered a candidate theory for further review and development.
- It is recognized that the characteristics of included publications is skewed towards those published in the USA and that there may be other frameworks internationally. However, it is relevant to note that there are a greater number of medical education facilities in the USA than other countries included such as Australia, New Zealand and Sweden.
- Research into competence and competency standards is dynamic and frameworks included are from varied time periods. This may limit application of this work to modern standards.

INTRODUCTION

Globally, 11 million deaths are attributable to suboptimal diet annually (1). Furthermore, in 2014, more than 1.9 billion adults were overweight, while 462 million were underweight. This coexistence of undernutrition, along with overweight and obesity, or diet-related chronic diseases, is referred to as the double burden of malnutrition. This burden is universal and presents an imperative to improve the nutrition capacity of the health workforce (2). Nutrition is a powerful tool for the prevention and management of diet-related chronic diseases (1). Nutrition care refers to any intervention performed by a health professional to improve the nutrition behaviour and subsequent health status of an individual or community and has been shown to improve diet-related and health outcomes, often with reduced risk, side effects and costs when compared with pharmacological interventions (3, 4). For example, when doctors provide nutrition advice as part of prenatal care, their patients have fewer complications associated with pregnancy and give birth to healthier children (5). In fact, a recent systematic analysis reports that improvement of diet could potentially prevent one in every five deaths globally (1). Furthermore, public health legislation such as the Patient Protection and Affordable Care Act (Sections 4001(d)(3), 4004(c)(d), 4103(b) and 4206) recognise the increased need for preventive healthcare interventions, such as nutrition care and authorises investments in training health professionals (6). Other countries, such as Australia, have not updated their National Nutrition Policy in over 25 years, while the National Healthy Food and Drink Policy in New Zealand does not include any reference of training of health professionals (7, 8). The World Health Organization (WHO) reiterate the need for increased investments in nutrition for improved health and successful development; the objectives of Universal Health Coverage cannot be achieved until nutrition actions are integrated across the health care continuum (9). Therefore, it is essential that clinicians of all backgrounds are cognizant of the role of nutrition in health and are well-equipped to initiate and support nutrition care as part of routine clinical practice.

Medically trained clinicians are well-placed to initiate and support patient nutrition care (10), in part due to their regular contact with the individuals for whom they provide care. For example, 88% of individuals are likely to see a general practitioner (primary care physician) annually (11). Furthermore, in a hospital setting, an estimated 13% to 69% of hospitalized individuals are malnourished on admission, and importantly, the prevalence is also high pre-discharge (12-15). Despite this, a recent systematic review indicates that medical education

remains insufficient to support clinicians to provide nutrition care as part of routine clinical practice (16). There are a number of organizations calling for improved nutrition education for physicians (17). Competency standards provide a framework for workforce development and are essential for the delivery of safe, effective and patient-centred care (18) and a vehicle for aligning the health priorities of the country with the values of a profession (19). This is particularly relevant, as there is an existing disconnect between medical education and the exigent double burden of malnutrition (16). While there are many approaches to developing a competency framework, authors argue that a preoccupation with discipline-specific tasks overlooks the relevance of cross-cutting attributes such as critical thinking, communication and collaboration which align outcomes across disciplines (18, 20). An integrated approach to competency encompasses the ability to combine and apply practical and reflexive competence in different contexts (20). The use of competency standards in improving medical nutrition education has been previously established and has been shown to increase a clinician's ability to integrate nutrition into patient care (4). Competency in nutrition care is important in the delivery of safe, effective and co-ordinated care (21). However, there is a recognised need to establish consensus on relevant nutrition competencies for medicine (16). The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally. As the UN *Decade of Action on Nutrition 2016-2025* is well underway, this is a timely and important review (22).

METHODS

This review was an integrative literature review, a "form of research that reviews, critiques and synthesises representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" (23). This methodology is considered rigorous in this context, and was selected as it allows for a combination of various study designs and data sources to be included (24, 25). Data, namely, nutrition competencies, were extracted into summary tables (24) and this matrix was then used to identify common themes and compare, contrast and analyse the literature (26). Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review (27-29). These frameworks acknowledge the complexity of clinical competence and the process of skill acquisition including the application of knowledge in practice. Furthermore, Miller's pyramid and the Dreyfus model of skill acquisition have been previously used as a theoretical framework on which to underpin and improve educational practice in the field of medicine (30-

33). These frameworks were therefore utilised as a theoretical blueprint for the organisation of nutrition competencies identified in this review. For the purposes of this review, we initially defined key concepts based on published definitions and author experience (Table 1).

Table 1. Definitions of key concepts used within this review

Concept	Definition
Competency (or competency standard)	A measure used to describe the idealized capacity of an individual to perform a role or set of tasks (34).
Competence	Competence can be described as the ability to perform a task with desirable outcomes under varied circumstances. This definition encompasses multiple components such as the habitual and judicious application of knowledge, technical skills, values, clinical reasoning and attitudes (35, 36).
Domains of competence	Competency domains represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (37).
Competency framework	A competency framework represents a complete collection of competencies required for effective performance (18).
Curriculum framework	A curriculum framework is an organised set of standards or learning objectives that define educational requirements

Search methods

CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched through April 2020 to identify published nutrition competency frameworks for medical education. The search strategy for each database is provided in Supplementary Materials. In brief, the key concepts were related to medically trained clinicians, nutrition and diet and competency. A research team comprised of all authors in this study, as well as a medical librarian, agreed upon terms with the aim of avoiding researcher bias when selecting articles. This search was complemented by handsearching reference lists of literature deemed relevant.

Inclusion criteria for this review were original research publications representing nutrition competencies for the continuum of medical education (pre- and post-registration). We included interdisciplinary nutrition competency frameworks if the framework stipulated use by the

medical profession. We excluded frameworks which included only limited reference to nutrition. For example, if a framework was specific to a disease, condition, or specialty rather than only nutrition, the paper was excluded (for example CVD-related frameworks which only included a reference to possible nutrition therapy). We included only current versions of frameworks and excluded editorials, reviews, conference proceedings, opinion papers and interviews. Grey literature was also reviewed by searching the reference lists of literature deemed relevant. The results of the search were not limited by time or language.

Search outcome

All database searches were directly imported into the electronic reference management tool Endnote© Version X9 (Clarivate Analytics, Philadelphia, USA) and grey literature searches were manually entered by the primary author (BL). After the removal of duplicates using EndNote and manually, one author (BL) independently screened titles and abstracts and selected studies according to the pre-defined inclusion criteria. If the abstract was not sufficient, full texts of remaining papers were screened independently to identify publications for inclusion. Where it was not clear, the primary author engaged in consultative and iterative discussion amongst authors to reach consensus. All authors reached consensus on the included articles.

Data analysis

Data extraction was completed independently by the primary researcher (BL). Information relating to nutrition competencies was extracted from the retained articles. Information discussing the nutrition-related knowledge, skills or attitudes which published authors believed medical practitioners needed to obtain was categorised as a competency and recorded. Similarly, competency domains or themes represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (37). Information related to competency domains was also included. Data was extracted from each paper into a summary table and series of matrices. The following information was extracted from full-text publications and presented systematically: citation and country, organisation/group, name of the framework, nutrition domains (if stated), nutrition competencies, learning objectives (if stated) and the level of medical education that

the framework is intended for (e.g. residency). Findings were read, re-read and articles compared and contrasted to identify patterns and relationships.

Quality appraisal

To determine quality and risk of bias for review, the full text of each article was assessed independently for quality (including risk of bias) by the primary researcher (BL). Given the variation in research methodologies, the Critical Appraisal Skills Programme (CASP) tool was modified for use, as adapted by Halcomb et al. (2016) (CASP, 2019; Halcomb et al., 2016).

Patient and Public Involvement

There is no patient and public involved in the study.

RESULTS

Search results

The total yield from all databases was 19,709 results. This was reduced to 14,023 results after the removal of duplicates. Using the exclusion criteria against title and abstract, a total of 56 full-text publications were assessed for eligibility, including four publications identified through hand searching of reference lists (Figure 1). It is of interest to note that a considerable number of results were related to the impact of a nutrition course or competency framework on nutrition knowledge, skills and attitudes and therefore not eligible for inclusion. Following full-text review, 11 articles were included in the review. Reasons for exclusion included papers which did not include competencies or a framework (n=18) and competencies that are not specific to nutrition or competencies for a specific aspect of nutrition or health care (for example cardiovascular disease nutrition competencies) (n=15). A list of excluded studies along with reasons for exclusion is provided in Online Supplementary Materials.

Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

Characteristics of included publications

Included studies were published between 1983 and 2019. The majority were peer-reviewed articles (n=7), with the remaining grey literature comprising of documented frameworks form expert professional groups (for example, professional associations or accrediting bodies) (n=3) and a position statement (n=1). Seven studies were from the USA, with one study from each of Australia and New Zealand, Africa, Sweden and the UK.

Quality appraisal

Descriptions of how the competency frameworks were developed varied in level of detail. It is important to note that few publications reported the research methods used to develop their frameworks. Furthermore, few publications acknowledged the limitations or weaknesses of the processes used to develop the competency frameworks (Question 5). Given these limitations, articles that did not achieve a 'yes' on all items of the checklist were not excluded from the review, but the appraisal was taken into consideration in the overall rigour of the present review (Table 2).

Table 2. Quality appraisal

1. Was the research design appropriate to address the aims of the research?
2. Was the data collected in a way that addressed the research issue?
3. Was the data analysis sufficiently rigorous?
4. Is there a clear statement of the study findings?
5. Are there limitations or weaknesses of the study acknowledged?
6. Is the research valuable?

	Q1	Q2	Q3	Q4	Q5	Q6
American Academy of Family Physicians, 1998	Unclear			Yes	No	Yes
Asp et al., 1995	Unclear					Yes
Cuerda et al., 2019	Yes	Yes	Unclear	Yes	No	Yes
Deen, Karp & Lowell, 1994	Unclear			Yes	No	Yes
Deakin University Strategic Teaching and Learning Grant Steering Committee, 2016	Yes	Yes	Unclear		No	Yes
Jhpiego & Save the Children, 2012	Yes	Yes	Yes	Yes	No	Yes
Lindsley et al., 2017	Yes	Yes	Yes	Yes	No	Yes
Maillet & Young, 1998	Unclear			Yes	No	Yes

Sierpina et al., 2016	Unclear				Yes	Yes
Young et al., 1983	Yes	Yes	Yes	Yes	Yes	Yes
ICGN Undergraduate Nutrition Education Implementation Group, 2013	Unclear					Yes

Competency domains

Five of eleven publications (45%) explicitly used competency domains to categorise or sub-divide nutrition competencies. Different methods of classification, or domains, included type of competency (such as knowledge, skills and attitudes), domains of human nutrition (including concepts of basic nutrition, concepts of applied nutrition and principles of clinical nutrition) and sub-division of competencies by nutrition concept (for example, macronutrients and micronutrients) or by elements of nutrition care (for example, diagnosis, treatment, prevention) (38-43). The most common competency domains were related to the role of nutrition in health promotion and disease prevention (n=3), nutrition assessment (n=2) and nutrition management (n=2) (39, 40, 42). Competency domains which were identified but only found within one framework included those related to patient nutrition counselling skills, nutrition referral, nutrition evidence, aspects of critical nutrition care (such as enteral and parenteral nutrition) and the impact of disease on nutrition (39, 42).

The Nutrition Competency Framework (NCF) for medical graduates, developed by the Deakin University Strategic Teaching and Learning Grant Steering Committee in Australia, was the only framework in this review purposefully mapped to a medical framework, namely, the Australian Medical Council (AMC) Graduate Outcome Statements (41, 44). Other frameworks in this review, published in the United Kingdom, are endorsed by statutory bodies such as the General Medical Council (GMC) and Medical Schools Council (42, 45, 46). Some inter-disciplinary nutrition competency frameworks also delineated competencies, such as by amount of patient education responsibility or by level of service delivery, to emphasise the relevance of nutrition competencies for the wider health workforce (47, 48).

Despite differences in the taxonomy and language across included nutrition competencies for medical education, there are some common underlying themes, which in some contexts may be considered “domains” if the papers are summarised. Specifically, five common themes were identified across the included nutrition competencies, including clinical practice (all 11

publications), health promotion and disease prevention (n =8), communication (n=7), working as a team (n=7) and professional practice (n=3). These themes overlap with existing medical competency standards and could be considered cross-cutting.

Competencies

Twenty-five unique nutrition competencies for medical education were identified in the 11 publications. Fifteen of twenty-five nutrition competencies for medicine were classified as knowledge/behaviour-based competencies. For example, 'Demonstrate knowledge of the functions of essential nutrients' (39, 43). Seven nutrition competencies were classified as skill-based (for example, 'Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease' (39, 41-43, 47-51)) and only four competencies were attitude/value-based (for example, 'Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status' (39) (Table 3). The most common nutrition competencies (suggested in greater than 50% of articles), were related to 1) skills in nutrition assessment, 2) the ability to prescribe dietary interventions in the prevention and treatment of disease, 3) knowledge of the role of nutrition in health promotion and disease prevention and 4) knowledge of the social and cultural importance of food, including food consumption trends and current nutrition recommendations. Authors less commonly suggested the relevance of demonstrating competency in how disease can affect nutritional status, food-borne illness, an awareness of personal health and nutrition and a commitment to provide evidence-based nutrition care for all patients regardless of health status. Articles published in developed countries were more likely to recommend competencies related to nutritional management of chronic diseases, while studies originating from developing countries included competencies related to emergency medicine and nutritional management for people living with HIV and AIDS (39, 48). One paper specified cross-cutting nutrition competencies for all health professionals including community mobilisation and nutrition counselling (48).

Table 3. Nutrition competencies for medicine

Theme and number of publications which include this theme	Domain	Competency	Competency Type	n[a]
Clinical Practice n=11 (100%)	Nutrition Assessment	Demonstrate skills in the assessment of nutritional health including the ability to calculate energy expenditure, nutrition requirements and body composition (21, 38, 39, 41-43, 47-51)	Skill	11
	Nutrition management	Demonstrate knowledge of evidence-based dietary strategies for prevention and treatment of disease (21, 38, 39, 41)	Knowledge/Behaviour	4
		Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease (39, 41-43, 47-51)	Skill	9
		Demonstrate knowledge of possible drug-nutrient interactions and prescribe accordingly (21, 38, 39, 43, 49)	Skill	5
		Demonstrate knowledge of breastfeeding and complementary feeding practices (39, 48)	Knowledge/Behaviour	2
	Nutrition monitoring and evaluation	Demonstrate the ability to monitor nutrition status and modify dietary recommendations as needed (49, 50)	Skill	2
Health promotion and disease prevention n=8 (73%)	Basic sciences as applied to nutrition	Demonstrate knowledge of the basic scientific principles of human nutrition (38, 39, 41)	Knowledge/Behaviour	3
		Demonstrate knowledge of nutrition applied to different stages of the life cycle (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate awareness of the nutritional content of food including the major dietary sources of macronutrients and micronutrients (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate knowledge of the difference between food allergies and food intolerance (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate knowledge of the functions of essential nutrients (39, 43)	Knowledge/Behaviour	2

		Demonstrate an understanding of how disease and its management can affect nutritional status (42)	Knowledge/Behaviour	1
	The role of nutrition in health promotion and disease prevention	Demonstrate an awareness of their own personal health and nutrition (21)	Attitude/Value	1
		Demonstrate knowledge of the role of nutrition in health promotion and disease prevention (38, 39, 41-43, 47, 51)	Knowledge/Behaviour	7
		Demonstrate knowledge of the social and cultural importance of food, including awareness of food consumption trends and current nutrition recommendations (21, 38, 39, 41, 43, 51)	Knowledge/Behaviour	6
		Demonstrate knowledge of nutrition-related causes of mortality and morbidity in the population (21, 38, 51)	Knowledge/Behaviour	3
		Demonstrate knowledge of the principles of public health nutrition, including strategies to reduce the burden of disease (39, 48)	Knowledge/Behaviour	2
		Describe food-borne illnesses and outline the process of reporting and investigating outbreaks of these illnesses (39)	Knowledge/Behaviour	1
Communication n=7 (64%)	Nutrition counselling skills	Demonstrate the ability to effectively provide nutrition education and counselling (21, 38, 39, 43, 47, 50)	Skill	6
		Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status (39)	Attitude/Value	2
Working as a team n=7 (64%)	The Multidisciplinary Team Approach to nutrition care	Demonstrate the ability to work effectively in a multidisciplinary team to deliver nutrition care, including the ability to refer onwards (21, 39, 41, 47, 49)	Skill	5
		Demonstrate knowledge of the role of other health professionals and community services in the multidisciplinary approach to nutrition care (39, 43, 51)	Knowledge/Behaviour	3
Professional Practice n=3 (27%)	Critical thinking	Demonstrate ability to think critically including the ability to interpret nutrition evidence and apply appropriately in clinical practice (21, 39, 41, 43, 50)	Skill	3
	Ethics	Demonstrate the ability to consider and apply principles of ethics related to nutritional management (38, 39, 41)	Attitude/Value	2

		Demonstrate a commitment to promote sound nutritional decision-making and appropriate levels of physical activity for all patients regardless of health status (39)	Attitude/Value	1

283 [a]**Number of articles which include this competency**

Level of medical education:

All 11 articles specified the level of medical education where there would be an expectation to teach and achieve the nutrition competencies. Five articles included nutrition competencies for undergraduate and graduate (entry-level) medical education. Three of the 11 articles stipulated use by primary care providers and one paper included competencies for family practice residents. The remaining two articles merely specified use by "practicing physicians".

Summary of concepts

A summary nutrition competency framework, adapted from Hughes et al. (2012) (20) and informed by the Dreyfus model of skill acquisition, the framework for clinical competency assessment outlined in Miller (1990) and the Knowledge to Action Cycle as described by Graham and colleagues (2006) (20, 27, 28, 52, 53) is presented based on the competencies in the literature (Figure 2). This provides a preliminary model for a nutrition competency framework for medicine, which can be further investigated in subsequent research. In this framework, categories of competency units are delineated into four different tiers to represent hierarchies of competency acquisition and assessment. At the base of the matrix are enabling and critical competencies (know and know how) which underpin higher level nutrition practice behaviours. At a foundational level, the Dunning-Kruger Effect indicates that individuals may be 'unconsciously unskilled' (54). The proposed framework also includes common, cross-cutting attributes identified in this review. Cross-cutting competencies delineate the professionalism required for effective, collaborative and safe practice and improve the transferability of the competency framework across health disciplines (20). Top-level practice competencies are defined by Hughes et al. (2012) as "higher order composite behaviours" which are required to "perform complex practice behaviours" which underpin core functions of the profession (20). Practice competencies involve behavioural performance (showing how and doing) and it is hoped the inclusion of these competencies bridges the gap between cognitive competencies and translation in practice (20).

Figure 2. Proposed conceptual nutrition competency framework for medicine

DISCUSSION

There is currently no consensus on nutrition competencies relevant for medical education. This review provides a critical synthesis of published nutrition competencies for medical education and practice internationally. This review identified five common themes across nutrition competencies which add to existing literature related to medical nutrition education. Twenty-five unique nutrition competencies for medical education were identified from 11 articles.

The five common themes across nutrition competencies for medicine, were clinical practice, health promotion and disease prevention, communication, working as a team and professional practice. The latter three, while referring to nutrition, highlighting generic skills that are required to be applied across all aspects of medical care. This is congruent with core competencies and individual roles in existing medical frameworks, such as the CanMEDS Physician Competency Framework, the Accreditation Council for Graduate Medical Education (ACGME) core competencies, the General Medical Council (GMC) Outcomes for graduates, the Australian Medical Council Limited (AMC) Graduate Outcome Statements and the Royal Australasian College of Physicians (RACP) Professional Practice Framework (44, 55-58). For example, the CanMEDS Physician Competency Framework, one of the most globally recognized health care profession competency frameworks articulates a number of intrinsic roles which reflect key themes identified in this review, such as the Communicator, Collaborator and Health Advocate.

Generic themes such as those identified in this review can provide leverage in educational reform, by aligning incentives to facilitate synergy across health care professions (59). For example, a multidisciplinary team (MDT – identified as "working as a team" in this review) approach to nutrition care has been shown to provide high quality, cost-effective nutrition outcomes (60, 61). However, there is a disconnect between the university education environment, which is generally not interdisciplinary, and the practice environment, which increasingly requires collaborative skills (59). Furthermore, communication and collaboration are key aspects of the iterative process of knowledge translation, including the ability to exchange information to overcome barriers to implementation. Communication and collaboration (teamwork) were also common themes identified by this review. Optimized knowledge translation has been shown to improve the quality of evidence-based nutrition care and strengthen the health care system, as summarised by the Knowledge to Action Cycle (53).

Not only does this cross-over between medical and nutrition competencies highlight the lateral nature of nutrition as a cognate scientific discipline, but it also provides merit to opportunity for the vertical integration of nutrition competencies into existing medical education. Rather than an isolated concept with a distinct set of competencies, existing medical spiral curricula could be enhanced by applying existing medical competencies to a nutrition context. Deen (2006) illustrated this by successfully mapping the Curriculum Committee of the National Academic Award (NAA) learning objectives to the ACGME competencies for competency-based resident evaluation (62). This reiterates the relevance of nutrition as a core facet of clinical practice without necessarily adding time to curricula. Namely, vertical integration of nutrition competencies into medical education is particularly relevant in a crowded curriculum, and is a key element of a successful integrated medical nutrition curriculum, shown to improve medical students' perceptions of nutrition as part of total patient care (63, 64). However, there is a need to first build consensus on nutrition competencies for medical education

The majority of the medical nutrition competencies identified in this review were knowledge-based, while less than 30% of nutrition competencies were skill-based and only four competencies were attitude-based (Table 3). While knowledge-based (enabling) competencies are essential to interpret new concepts in nutrition and underpin higher order (practice) competencies, skill-based competencies are relevant to clinical practice, which requires the complex and judicial application of knowledge, technical skills, clinical reasoning, values and reflection under varied circumstances (36). This is in line with the experience of medical graduates and practising physicians, who do not feel comfortable or adequately prepared to provide nutrition counselling to their patients (10, 16, 65, 66). In order to overcome these barriers, Adams et al., (2010) and Lindsley et al., (2017) emphasise the need for "skill-centred nutrition training" (67). A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals, reports that educational interventions which led to improvements in the delivery of nutrition care focused on skills and attitudes rather than just knowledge (68). Skill-based nutrition training has been shown to improve medical students' nutrition knowledge and confidence in lifestyle counselling (69).

While competency frameworks provide an architectural blueprint for constructing educational programmes, the centrality of valid assessment methods to support the life-long journey of competency development cannot be overlooked (19). Increasing the weighting of a topic in

assessment has been shown to enhance medical students' reported motivation to learn about the topic (70). Furthermore, regular and repeated assessment can improve knowledge retention in medical students (71, 72). This is particularly important given that despite initial high interest in nutrition, interest in and perception of the importance of nutrition may decline during time in medical school (73). Earlier research highlights the effectiveness of the Objective Structured Clinical Exam (OSCE) in evaluating the ability to synthesise and translate knowledge to clinical practice (64). Miller (1990) also emphasises the role of skill-based assessment methods such as the OSCE in the appraisal of technical and clinical competence (74). Problem-based learning tutorials, culinary skills training and clinical case presentations have also been shown to promote active learning and lead to significant changes in participants' knowledge, personal health habits, confidence to provide dietary counselling and ability to nutritionally manage malnutrition (68). A combination of innovative learning strategies is required to support the development of clinical competence. Educational strategies and assessment methods which improve nutrition care competencies, such as problem-based learning and the OSCE, are already widely used methods in medical education (75). Therefore, the application of existing learning to a nutrition context, such as a nutrition OSCE, may lead to improvements in competency to provide nutrition care in future practice. There is currently no consensus on the required nutrition competencies for medicine, which presents a further barrier to the integration of nutrition in medical education (16). The nutrition competencies identified in this review provide a potential benchmark for the nutrition knowledge, skills and attitudes to be included in curricula (Table 3). However, given the lack of consensus on relevant nutrition competencies, commitment of individual institutions to compulsory nutrition education is insufficient and regulation is required. The 2019 report 'Doctoring Our Diet' recommends policy levers to include nutrition in U.S. medical training, such as government investment to provide financial incentive for the inclusion of nutrition in medical training, amending accreditation standards to mandate requirements for nutrition education, increasing representation of nutrition in step and board-examinations and compulsory nutrition training in continuing medical education (17).

STRENGTHS AND LIMITATIONS

This review offers a critical and timely synthesis of medical nutrition competencies and a conceptual nutrition competency framework. As an integrative review, this framework might be considered a candidate theory for further review and development. However, this review

also needs to be considered in the context of its limitations. While the search strategy used included terms previously used to identify competency frameworks, others may exist and therefore some studies may not have been captured. It is recognized that the characteristics of included publications is skewed towards those published in the USA (and English language) and that this may have biased our findings. However, it is relevant to note that there are a greater number of medical education facilities in the USA than other countries included such as Australia, New Zealand and Sweden (76). The majority (6/7) of the included studies were published in developed countries; this may have implications on the generalisability of the proposed nutrition competency framework. We used the Dreyfus model of skill acquisition, Miller's hierarchy for the assessment of clinical competence and the Knowledge to Action Cycle (20, 27, 28, 52, 53) to frame this work, and acknowledge that other frameworks may also be useful in this context. For example, the frameworks used may not consider elements of cognitive aptitude such as diagnostic reasoning.

CONCLUSION

This review identified five common, cross-cutting themes across nutrition competencies for medicine: 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based. The most common nutrition competencies were related to nutrition assessment, dietary interventions for the prevention and treatment of disease, the role of nutrition in health promotion and disease prevention and knowledge of the social and cultural importance of food. This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Acknowledgements: We would like to thank Isla Kuhn, Medical Librarian at the University of Cambridge for her invaluable input to the search strategy.

Contributors: BL, EB, KM and SR contributed to the design of the review. BL did the literature search, performed data analysis and drafted the manuscript. EB contributed to data extraction. All authors contributed to revision of the manuscript and approval of the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Patients and/or the public were not involved in this study.

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests: None declared.

Patient consent for publication: Not required

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Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

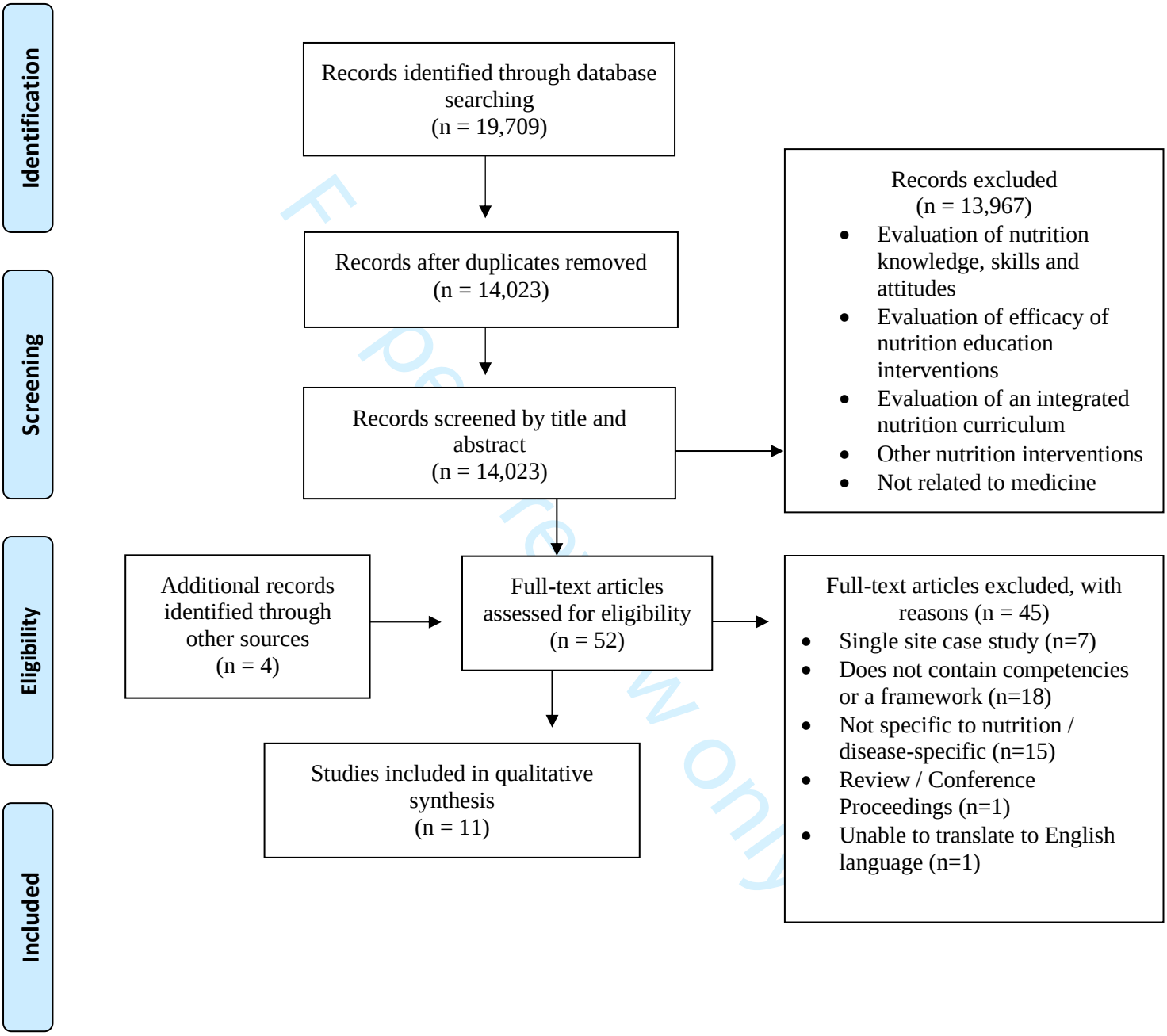
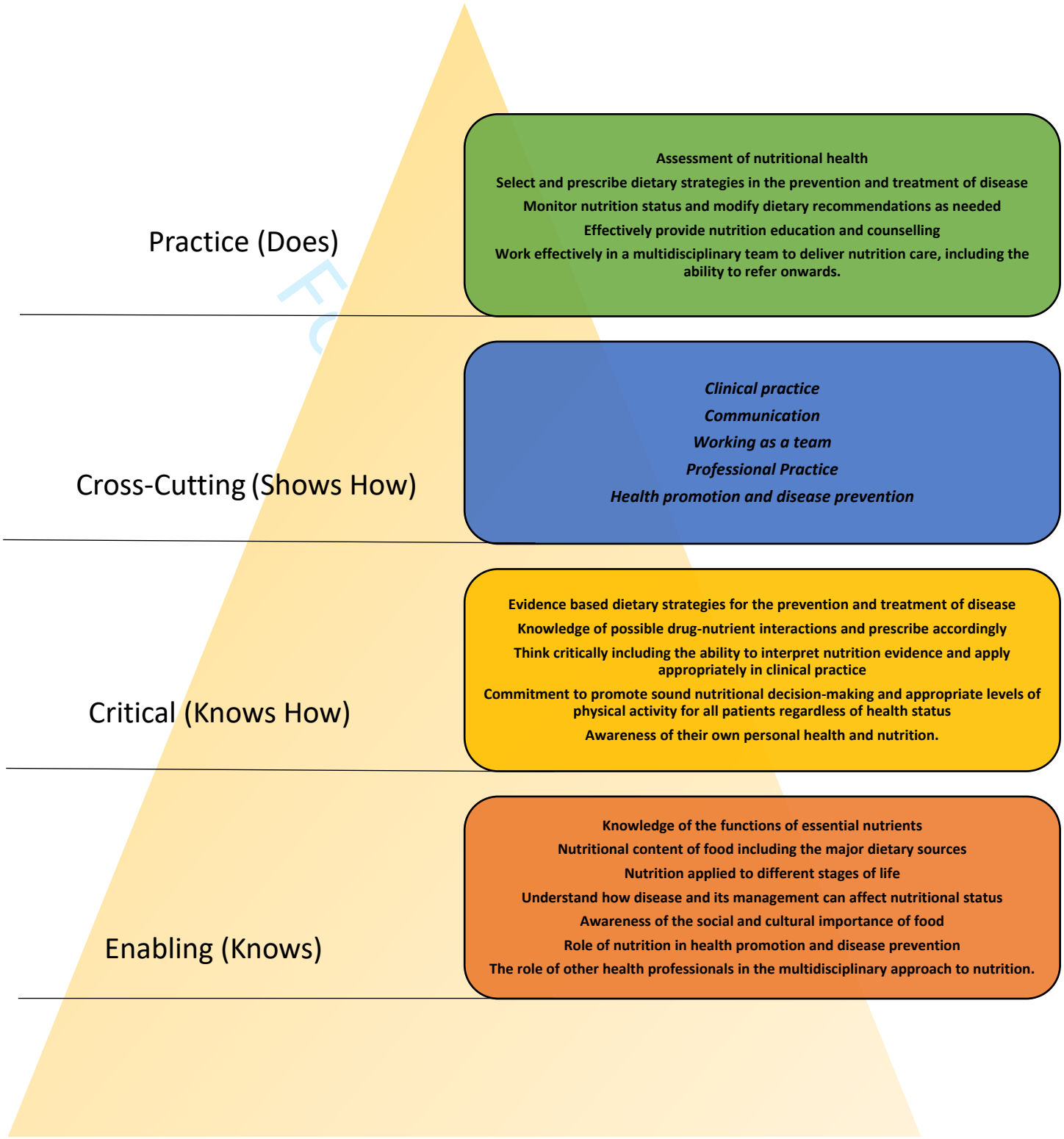


Figure 2. Proposed conceptual nutrition competency framework for medicine



Supplementary Materials 1 – Search Strategy

Data base	Search terms	Results
CINAHL Plus with Full Text	(((“doctor*” OR (“physicians+”)) OR (“medical student*”) OR ((“students, medical”) OR “(medic* OR doctor* OR clinical*) N2 student*”) OR ((“general practitioner” OR family doctor* OR family physician*”) OR (“physicians, family”)) OR ((“interns and residents”) OR “medical N3 (specialist* OR intern* OR resident*))” OR (specialist registrar*) OR (clinical specialist*) OR ((“education, medical+”) OR “medical education” OR (“education, medical, continuing”)) OR (“undergraduate medical education”) OR (“postgraduate medical education”) OR ((“nutrition education) OR “nutrition education” OR (“nutritional physiology+”)) OR (“medical nutrition education”) AND ((“nutrition”) OR “nutrition*” OR (“public health nutrition”) OR (“nutrition services+”) OR (“nutrition policy+”)) OR ((“diet”) OR “diet*”) OR ((“life style+”) OR “lifestyle”) AND ((competen*) OR ((“clinical competence+”) OR “clinical competen*”) OR ((“education, competency-based”) OR “competency-based education”) OR ((“curriculum+”) OR “curricul*”) OR (“competency framework*” OR (“professional competence+”)) OR (competency standard*)))	2650
Embase	(((doctor*) OR (physician* OR ‘physician’/exp) OR (‘hospital physician’/exp) OR (medical student* OR ‘medical student’/exp) OR ((medic* OR doctor* OR clinical*) NEAR/2 student*) OR (medical NEAR/3 (specialist* OR intern* OR resident*)) OR (specialist registrar* OR ‘medical specialist’/exp) OR (clinical specialist*) OR (medical education OR ‘medical education’/exp) OR (undergraduate medical education) OR (graduate medical education OR ‘residency education’/exp) OR (nutrition education OR ‘nutrition education’/exp OR ‘health education’/exp) OR (medical nutrition education)) AND ((nutrition* OR ‘nutrition’/exp OR ‘nutrition service’/exp) OR (diet* OR ‘diet’/exp) OR (lifestyle* OR ‘lifestyle’/exp OR ‘lifestyle modification’/exp)) AND ((competen* OR ‘competence’/exp) OR (clinical competen* OR ‘clinical competence’/exp) OR (curricul* OR ‘curriculum’/exp OR ‘medical school’/exp) OR (competency framework* OR ‘professional competence’/exp) OR (competency standard*)))	7695
Global Health	(((doctor* OR physician+) OR (medical student* OR medical students) OR ((medic* OR doctor* OR clinical*) N2 student*) OR ((general practitioner* OR gp* OR family doctor* OR family physician*) OR general practitioners) OR (medical N3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR (clinical specialist*) OR (medical	1280

	education OR medical education+) OR (undergraduate medical education OR medical schools) OR (graduate medical education OR continuing education OR medicine+) OR (nutrition education) OR (medical nutrition education)) AND ((nutrition* OR nutrition+ OR nutrition programmes OR nutrition physiology OR nutrition planning OR nutrition information OR clinical nutrition OR community nutrition OR nutritional support OR nutritional intervention OR nutritional assessment) OR (diet* OR diet OR diet counselling OR diet planning) OR (lifestyle* OR lifestyle)) AND ((competen* OR professional competence) OR (clinical competen*) OR (competency-based education) OR (curricul* OR curriculum+ OR curriculum guides) OR (competency framework*) OR (competency standard*)))	
Medline	((("doctor*") OR ("physician*") OR ((medic* OR doctor* OR clinical*) NEAR/2 "student*") OR ("medical student*") OR (("general practitioner* OR gp* OR family doctor* OR family physician*") OR "physicians, family" OR "general practitioners") OR (("medical NEAR/3 (specialist* OR intern* OR resident*)" OR "internship and residency" OR "internal medicine+") OR ("specialist registrar*") OR ("clinical specialist*") OR ("medical education" OR "education, medical+" OR "education, medical, undergraduate+" OR "education, medical, continuing" OR "education, premedical") OR ("postgraduate medical education") OR ("nutrition education" OR "nutritional sciences+")) AND ((competen*) OR ("competency-based education" OR "clinical competence" OR "professional competence+") OR ("curricul*" OR "curriculum+") OR ("competency framework*) OR ("competency standard*)) AND ("nutrition*" OR "nutrition therapy+") OR ("diet*" OR "diet+" OR "diet therapy+") OR ("lifestyle*" OR "life style+")))	3605
Scopus	(((doctor* OR ((medic* OR doctor* OR clinical*) W/2 student*) OR ("medical student") OR ("general practitioner*" OR gp* OR "family doctor*" OR "family physician*") OR (medical W/3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR ("clinical specialist*") OR ("medical education") OR ("undergraduate medical education") OR ("postgraduate medical education")) AND ((nutrition*) OR (diet*) OR (lifestyle* OR "life style")) AND ((competen*) OR ("clinical competen*") OR ("competency-based education") OR (curricul*) OR ("competency framework") OR ("competency standard*")))	2382
Web of Science	(((doctor*) OR (physician*) OR (medical student*) OR (student* NEAR/2 (medic* OR doctor* OR clinical*)) OR (general practitioner* OR gp OR family doctor* OR family physician*) OR (medical NEAR/3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR (clinical	2097

	specialist*) OR (medical education) OR (undergraduate medical education) OR (postgraduate medical education) OR (nutrition education) OR (medical nutrition education)) AND ((nutrition*) OR (diet*) OR (lifestyle* OR life style)) AND ((competen*) OR (clinical competen*) OR (competency-based education) OR (curricul*) OR (competency framework*) OR (professional competen*) OR (competency standard*)))	
Total yield from all databases		**19709**

Supplementary Materials 2 – List of excluded studies along with reasons for exclusion

Full-text articles excluded, with reasons (n=45)

- Single site case study (n=7)
- Does not contain competencies or a framework (n=18)
- Not specific to nutrition / disease-specific (n=15)
- Review / Conference Proceedings (n=1)
- Unable to translate to English language (n=1)

Study	Reason for Exclusion
Adams et al., 2010	Does not contain competencies or a framework
Akner & Vessby, 1997	Does not contain competencies or a framework
Al-Nimr et al., 2019	Single site case study (Not formally adopted or endorsed)
Asp et al., 1995	Does not contain competencies or a framework
Aspry et al., 2018	Framework not specific to nutrition (Competencies for ASCVD prevention)
Bairey Merz et al., 2009	Framework not specific to nutrition (Competencies specific to the prevention of cardiovascular disease)
Bakemeier et al., 1989	Framework not specific to nutrition (Nutrition and cancer education objectives)
Ball et al., 2010	Single site case study (Not formally adopted or endorsed)
Brodribb et al., 2012	Framework not specific to nutrition (Competencies specific to breastfeeding)
Chamberlain et al., 1989	Does not contain competencies or a framework
Cooksey et al., 2000	Does not contain competencies or a framework
Cresci et al., 2019	Does not include competencies or a framework
Committee of the Nutrition Academic Award Program, 2002	Does not contain competencies or a framework
Dahl, 2006	Does not include competencies or a framework
Edwards & Rosenfeld, 2006	Single site case study (Not formally adopted or endorsed)
Gallagher et al., 1979	Does not contain competencies or a framework
Hark et al., 2000	Single site case study (Not formally adopted or endorsed)
Heimburger, 2002	Does not contain competencies or a framework
Heimburger, 2006	Does not contain competencies or a framework
Hivert et al., 2016	Does not contain competencies or a framework
Huang et al., 2009	Framework not specific to nutrition (Health and obesity: prevention and education curriculum)
Jackson, 2001	Review article
Jensen & Hessov, 1991	Does not contain competencies or a framework
Kaye et al., 2018	Does not contain competencies or a framework
Kelly et al., 2019	Framework not specific to nutrition (Competencies for lifestyle medicine intensivists)

Kligler et al., 2004	Framework not specific to nutrition (Competencies in integrative medicine)
Kushner et al., 2019	Framework not specific to nutrition (Obesity competencies)
Lianov et al., 2010	Framework not specific to nutrition (Physician competencies for prescribing lifestyle medicine)
Lin et al., 1999	Unable to translate to English from Chinese
Maiburg et al., 2004	Single site case study (Not formally adopted or endorsed)
Milla, 2002	Framework not specific to nutrition (European training syllabus in paediatric gastroenterology, hepatology and nutrition)
Mularski et al., 1997	Does not contain competencies or a framework
Mulder et al., 2016	Single site case study (Not formally adopted or endorsed)
Powell-Tuck et al., 1997	Does not contain competencies or a framework (course evaluation)
Ray et al., 2010	Does not contain competencies or a framework
Rock et al., 1995	Does not contain competencies or a framework
Rudolph et al., 1999	Framework not specific to nutrition (NASPGN guidelines for training in paediatric gastroenterology)
Ryen et al., 2003	Framework not specific to nutrition (Gastroenterology core curriculum)
Scolapio et al., 2008	Does not contain competencies or a framework
Somannavar, 2012	Single site case study (Not formally adopted or endorsed)
The Gastroenterology Leadership Council, 1996	Framework not specific to nutrition (Gastroenterology core curriculum)
Trilk et al., 2019	Framework not specific to nutrition (Lifestyle medicine curriculum)
Weinsier et al., 1989	Does not contain competencies or a framework (Priority rankings for nutrition topics to be included in curriculum)
Winick, 1993	Does not contain competencies or a framework
Withers et al., 2019	Framework not specific to nutrition (Core competencies in global health training)

BMJ Open

Nutrition Competencies for Medicine: An Integrative Review and Critical Synthesis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043066.R2
Article Type:	Original research
Date Submitted by the Author:	22-Feb-2021
Complete List of Authors:	Lepre, Breanna; University of Wollongong, School of Medicine; NNEdPro Global Centre for Nutrition and Health, Mansfield, Kylie; University of Wollongong, School of Medicine, University of Wollongong, and Illawarra Health & Medical Research Institute Ray, Sumantra; NNEdPro Global Centre for Nutrition and Health, St. John's Innovation Centre Beck, Eleanor; University of Wollongong, School of Medicine, University of Wollongong and Illawarra Health & Medical Research Institute
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism
Keywords:	MEDICAL EDUCATION & TRAINING, NUTRITION & DIETETICS, EDUCATION & TRAINING (see Medical Education & Training)

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Nutrition Competencies for Medicine: An Integrative Review and Critical Synthesis

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Word Count (excluding title page, abstract, references, figures and tables): 4000

ABSTRACT

Objective: Globally, 11 million deaths are attributable to suboptimal diet annually, and nutrition care has been shown to improve health outcomes. While medically trained clinicians are well-placed to provide nutrition care, medical education remains insufficient to support clinicians to deliver nutrition advice as part of routine clinical practice. Competency standards provide a framework for workforce development and a vehicle for aligning health priorities with the values of a profession. Albeit, there remains an urgent need to establish consensus on nutrition competencies for medicine. The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally.

Design: Integrative review.

Data sources: CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched through April 2020.

Eligibility criteria: We included published nutrition competency frameworks. This search was complemented by handsearching reference lists of literature deemed relevant.

Data extraction and synthesis: Data were extracted into summary tables and this matrix was then used to identify common themes and to compare and analyse the literature. Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review.

Results: Using a pre-determined search strategy, 11 articles were identified. Five common themes were identified and include 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based.

Conclusions: This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Keywords: Competency-based education, Medical education, Nutrition competencies, Nutrition education

STRENGTHS AND LIMITATIONS OF THIS STUDY

- This review offers a critical and timely synthesis of medical nutrition competencies and a conceptual nutrition competency framework.
- Themes such as communication and teamwork are not specific to nutrition and highlight integration of topics across a curriculum.
- As an integrative review, this framework might be considered a candidate theory for further review and development.
- It is recognized that the characteristics of included publications is skewed towards those published in the USA and that there may be other frameworks internationally. However, it is relevant to note that there are a greater number of medical education facilities in the USA than other countries included such as Australia, New Zealand and Sweden.
- Research into competence and competency standards is dynamic and frameworks included are from varied time periods. This may limit application of this work to modern standards.

INTRODUCTION

Globally, 11 million deaths are attributable to suboptimal diet annually (1). Furthermore, in 2014, more than 1.9 billion adults were overweight, while 462 million were underweight. This coexistence of undernutrition, along with overweight and obesity, or diet-related chronic diseases, is referred to as the double burden of malnutrition. This burden is universal and presents an imperative to improve the nutrition capacity of the health workforce (2). Nutrition is a powerful tool for the prevention and management of diet-related chronic diseases (1). Nutrition care refers to any intervention performed by a health professional to improve the nutrition behaviour and subsequent health status of an individual or community and has been shown to improve diet-related and health outcomes, often with reduced risk, side effects and costs when compared with pharmacological interventions (3, 4). For example, when doctors provide nutrition advice as part of prenatal care, their patients have fewer complications associated with pregnancy and give birth to healthier children (5). In fact, a recent systematic analysis reports that improvement of diet could potentially prevent one in every five deaths globally (1). Furthermore, public health legislation such as the Patient Protection and Affordable Care Act (Sections 4001(d)(3), 4004(c)(d), 4103(b) and 4206) recognise the increased need for preventive healthcare interventions, such as nutrition care and authorises investments in training health professionals (6). Other countries, such as Australia, have not updated their National Nutrition Policy in over 25 years, while the National Healthy Food and Drink Policy in New Zealand does not include any reference of training of health professionals (7, 8). The World Health Organization (WHO) reiterate the need for increased investments in nutrition for improved health and successful development; the objectives of Universal Health Coverage cannot be achieved until nutrition actions are integrated across the health care continuum (9). Therefore, it is essential that clinicians of all backgrounds are cognizant of the role of nutrition in health and are well-equipped to initiate and support nutrition care as part of routine clinical practice.

Medically trained clinicians are well-placed to initiate and support patient nutrition care (10), in part due to their regular contact with the individuals for whom they provide care. For example, 88% of individuals are likely to see a general practitioner (primary care physician) annually (11). Furthermore, in a hospital setting, an estimated 13% to 69% of hospitalized individuals are malnourished on admission, and importantly, the prevalence is also high pre-discharge (12-15). Despite this, a recent systematic review indicates that medical education

remains insufficient to support clinicians to provide nutrition care as part of routine clinical practice (16). There are a number of organizations calling for improved nutrition education for physicians (17). Competency standards provide a framework for workforce development and are essential for the delivery of safe, effective and patient-centred care (18) and a vehicle for aligning the health priorities of the country with the values of a profession (19). This is particularly relevant, as there is an existing disconnect between medical education and the exigent double burden of malnutrition (16). While there are many approaches to developing a competency framework, authors argue that a preoccupation with discipline-specific tasks overlooks the relevance of cross-cutting attributes such as critical thinking, communication and collaboration which align outcomes across disciplines (18, 20). An integrated approach to competency encompasses the ability to combine and apply practical and reflexive competence in different contexts (20). The use of competency standards in improving medical nutrition education has been previously established and has been shown to increase a clinician's ability to integrate nutrition into patient care (4). Competency in nutrition care is important in the delivery of safe, effective and co-ordinated care (21). However, there is a recognised need to establish consensus on relevant nutrition competencies for medicine (16). The aim of this review is to provide a critical synthesis of published nutrition competencies for medicine internationally. As the UN *Decade of Action on Nutrition 2016-2025* is well underway, this is a timely and important review (22).

METHODS

This review was an integrative literature review, a "form of research that reviews, critiques and synthesises representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated" (23). This methodology is considered rigorous in this context, and was selected as it allows for a combination of various study designs and data sources to be included (24, 25). Data, namely, nutrition competencies, were extracted into summary tables (24) and this matrix was then used to identify common themes and compare, contrast and analyse the literature (26). Miller's pyramid, the Knowledge to Action cycle and the Dreyfus model of skill acquisition were also used to consider the results of this review (27-29). These frameworks acknowledge the complexity of clinical competence and the process of skill acquisition including the application of knowledge in practice. Furthermore, Miller's pyramid and the Dreyfus model of skill acquisition have been previously used as a theoretical framework on which to underpin and improve educational practice in the field of medicine (30-

33). These frameworks were therefore utilised as a theoretical blueprint for the organisation of nutrition competencies identified in this review. For the purposes of this review, we initially defined key concepts based on published definitions and author experience (Table 1).

Table 1. Definitions of key concepts used within this review

Concept	Definition
Competency (or competency standard)	A measure used to describe the idealized capacity of an individual to perform a role or set of tasks (34).
Competence	Competence can be described as the ability to perform a task with desirable outcomes under varied circumstances. This definition encompasses multiple components such as the habitual and judicious application of knowledge, technical skills, values, clinical reasoning and attitudes (35, 36).
Domains of competence	Competency domains represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (37).
Competency framework	A competency framework represents a complete collection of competencies required for effective performance (18).
Curriculum framework	A curriculum framework is an organised set of standards or learning objectives that define educational requirements

Search methods

CINAHL, Medline, Embase, Scopus, Web of Science and Global Health were searched through April 2020 to identify published nutrition competency frameworks for medical education. The search strategy for each database is provided in Supplementary Materials 1. In brief, the key concepts were related to medically trained clinicians, nutrition and diet and competency. A research team comprised of all authors in this study, as well as a medical librarian, agreed upon terms with the aim of avoiding researcher bias when selecting articles. This search was complemented by handsearching reference lists of literature deemed relevant.

Inclusion criteria for this review were original research publications representing nutrition competencies for the continuum of medical education (pre- and post-registration). We included interdisciplinary nutrition competency frameworks if the framework stipulated use by the

medical profession. We excluded frameworks which included only limited reference to nutrition. For example, if a framework was specific to a disease, condition, or specialty rather than only nutrition, the paper was excluded (for example CVD-related frameworks which only included a reference to possible nutrition therapy). We included only current versions of frameworks and excluded editorials, reviews, conference proceedings, opinion papers and interviews. Grey literature was also reviewed by searching the reference lists of literature deemed relevant. The results of the search were not limited by time or language.

Search outcome

All database searches were directly imported into the electronic reference management tool Endnote© Version X9 (Clarivate Analytics, Philadelphia, USA) and grey literature searches were manually entered by the primary author (BL). After the removal of duplicates using EndNote and manually, one author (BL) independently screened titles and abstracts and selected studies according to the pre-defined inclusion criteria. If the abstract was not sufficient, full texts of remaining papers were screened independently to identify publications for inclusion. Where it was not clear, the primary author engaged in consultative and iterative discussion amongst authors to reach consensus. All authors reached consensus on the included articles.

Data analysis

Data extraction was completed independently by the primary researcher (BL). Information relating to nutrition competencies was extracted from the retained articles. Information discussing the nutrition-related knowledge, skills or attitudes which published authors believed medical practitioners needed to obtain was categorised as a competency and recorded. Similarly, competency domains or themes represent organised clusters of competencies which are intended to characterise a central aspect of professional practice in which a professional should be competent (37). Information related to competency domains was also included. Data was extracted from each paper into a summary table and series of matrices. The following information was extracted from full-text publications and presented systematically: citation and country, organisation/group, name of the framework, nutrition domains (if stated), nutrition competencies, learning objectives (if stated) and the level of medical education that

the framework is intended for (e.g. residency). Findings were read, re-read and articles compared and contrasted to identify patterns and relationships.

Quality appraisal

To determine quality and risk of bias for review, the full text of each article was assessed independently for quality (including risk of bias) by the primary researcher (BL). Given the variation in research methodologies, the Critical Appraisal Skills Programme (CASP) tool was modified for use, as adapted by Halcomb et al. (2016) (CASP, 2019; Halcomb et al., 2016).

Patient and Public Involvement

There is no patient and public involved in the study.

RESULTS

Search results

The total yield from all databases was 19,709 results. This was reduced to 14,023 results after the removal of duplicates. Using the exclusion criteria against title and abstract, a total of 56 full-text publications were assessed for eligibility, including four publications identified through hand searching of reference lists (Figure 1). It is of interest to note that a considerable number of results were related to the impact of a nutrition course or competency framework on nutrition knowledge, skills and attitudes and therefore not eligible for inclusion. Following full-text review, 11 articles were included in the review. Reasons for exclusion included papers which did not include competencies or a framework (n=18) and competencies that are not specific to nutrition or competencies for a specific aspect of nutrition or health care (for example cardiovascular disease nutrition competencies) (n=15). A list of excluded studies along with reasons for exclusion is provided in Online Supplementary Materials 2.

Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

Characteristics of included publications

Included studies were published between 1983 and 2019. The majority were peer-reviewed articles (n=7), with the remaining grey literature comprising of documented frameworks form expert professional groups (for example, professional associations or accrediting bodies) (n=3) and a position statement (n=1). Seven studies were from the USA, with one study from each of Australia and New Zealand, Africa, Sweden and the UK.

Quality appraisal

Descriptions of how the competency frameworks were developed varied in level of detail. It is important to note that few publications reported the research methods used to develop their frameworks. Furthermore, few publications acknowledged the limitations or weaknesses of the processes used to develop the competency frameworks (Question 5). Given these limitations, articles that did not achieve a 'yes' on all items of the checklist were not excluded from the review, but the appraisal was taken into consideration in the overall rigour of the present review (Table 2).

Table 2. Quality appraisal

1. Was the research design appropriate to address the aims of the research?
2. Was the data collected in a way that addressed the research issue?
3. Was the data analysis sufficiently rigorous?
4. Is there a clear statement of the study findings?
5. Are there limitations or weaknesses of the study acknowledged?
6. Is the research valuable?

	Q1	Q2	Q3	Q4	Q5	Q6
American Academy of Family Physicians, 1998	Unclear			Yes	No	Yes
Asp et al., 1995	Unclear					Yes
Cuerda et al., 2019	Yes	Yes	Unclear	Yes	No	Yes
Deen, Karp & Lowell, 1994	Unclear			Yes	No	Yes
Deakin University Strategic Teaching and Learning Grant Steering Committee, 2016	Yes	Yes	Unclear		No	Yes
Jhpiego & Save the Children, 2012	Yes	Yes	Yes	Yes	No	Yes
Lindsley et al., 2017	Yes	Yes	Yes	Yes	No	Yes
Maillet & Young, 1998	Unclear			Yes	No	Yes

Sierpina et al., 2016	Unclear				Yes	Yes
Young et al., 1983	Yes	Yes	Yes	Yes	Yes	Yes
ICGN Undergraduate Nutrition Education Implementation Group, 2013	Unclear					Yes

Competency domains

Five of eleven publications (45%) explicitly used competency domains to categorise or sub-divide nutrition competencies. Different methods of classification, or domains, included type of competency (such as knowledge, skills and attitudes), domains of human nutrition (including concepts of basic nutrition, concepts of applied nutrition and principles of clinical nutrition) and sub-division of competencies by nutrition concept (for example, macronutrients and micronutrients) or by elements of nutrition care (for example, diagnosis, treatment, prevention) (38-43). The most common competency domains were related to the role of nutrition in health promotion and disease prevention (n=3), nutrition assessment (n=2) and nutrition management (n=2) (39, 40, 42). Competency domains which were identified but only found within one framework included those related to patient nutrition counselling skills, nutrition referral, nutrition evidence, aspects of critical nutrition care (such as enteral and parenteral nutrition) and the impact of disease on nutrition (39, 42).

The Nutrition Competency Framework (NCF) for medical graduates, developed by the Deakin University Strategic Teaching and Learning Grant Steering Committee in Australia, was the only framework in this review purposefully mapped to a medical framework, namely, the Australian Medical Council (AMC) Graduate Outcome Statements (41, 44). Other frameworks in this review, published in the United Kingdom, are endorsed by statutory bodies such as the General Medical Council (GMC) and Medical Schools Council (42, 45, 46). Some inter-disciplinary nutrition competency frameworks also delineated competencies, such as by amount of patient education responsibility or by level of service delivery, to emphasise the relevance of nutrition competencies for the wider health workforce (47, 48).

Despite differences in the taxonomy and language across included nutrition competencies for medical education, there are some common underlying themes, which in some contexts may be considered “domains” if the papers are summarised. Specifically, five common themes were identified across the included nutrition competencies, including clinical practice (all 11

publications), health promotion and disease prevention (n =8), communication (n=7), working as a team (n=7) and professional practice (n=3). These themes overlap with existing medical competency standards and could be considered cross-cutting.

Competencies

Twenty-five unique nutrition competencies for medical education were identified in the 11 publications. Fifteen of twenty-five nutrition competencies for medicine were classified as knowledge/behaviour-based competencies. For example, 'Demonstrate knowledge of the functions of essential nutrients' (39, 43). Seven nutrition competencies were classified as skill-based (for example, 'Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease' (39, 41-43, 47-51)) and only four competencies were attitude/value-based (for example, 'Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status' (39) (Table 3). The most common nutrition competencies (suggested in greater than 50% of articles), were related to 1) skills in nutrition assessment, 2) the ability to prescribe dietary interventions in the prevention and treatment of disease, 3) knowledge of the role of nutrition in health promotion and disease prevention and 4) knowledge of the social and cultural importance of food, including food consumption trends and current nutrition recommendations. Authors less commonly suggested the relevance of demonstrating competency in how disease can affect nutritional status, food-borne illness, an awareness of personal health and nutrition and a commitment to provide evidence-based nutrition care for all patients regardless of health status. Articles published in developed countries were more likely to recommend competencies related to nutritional management of chronic diseases, while studies originating from developing countries included competencies related to emergency medicine and nutritional management for people living with HIV and AIDS (39, 48). One paper specified cross-cutting nutrition competencies for all health professionals including community mobilisation and nutrition counselling (48).

281 **Table 3. Nutrition competencies for medicine**
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Theme and number of publications which include this theme	Domain	Competency	Competency Type	n[a]
Clinical Practice n=11 (100%)	Nutrition Assessment	Demonstrate skills in the assessment of nutritional health including the ability to calculate energy expenditure, nutrition requirements and body composition (21, 38, 39, 41-43, 47-51)	Skill	11
	Nutrition management	Demonstrate knowledge of evidence-based dietary strategies for prevention and treatment of disease (21, 38, 39, 41)	Knowledge/Behaviour	4
		Demonstrate ability to select and prescribe dietary strategies in the prevention and treatment of disease (39, 41-43, 47-51)	Skill	9
		Demonstrate knowledge of possible drug-nutrient interactions and prescribe accordingly (21, 38, 39, 43, 49)	Skill	5
		Demonstrate knowledge of breastfeeding and complementary feeding practices (39, 48)	Knowledge/Behaviour	2
	Nutrition monitoring and evaluation	Demonstrate the ability to monitor nutrition status and modify dietary recommendations as needed (49, 50)	Skill	2
Health promotion and disease prevention n=8 (73%)	Basic sciences as applied to nutrition	Demonstrate knowledge of the basic scientific principles of human nutrition (38, 39, 41)	Knowledge/Behaviour	3
		Demonstrate knowledge of nutrition applied to different stages of the life cycle (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate awareness of the nutritional content of food including the major dietary sources of macronutrients and micronutrients (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate knowledge of the difference between food allergies and food intolerance (38, 39, 43)	Knowledge/Behaviour	3
		Demonstrate knowledge of the functions of essential nutrients (39, 43)	Knowledge/Behaviour	2

		Demonstrate an understanding of how disease and its management can affect nutritional status (42)	Knowledge/Behaviour	1
	The role of nutrition in health promotion and disease prevention	Demonstrate an awareness of their own personal health and nutrition (21)	Attitude/Value	1
		Demonstrate knowledge of the role of nutrition in health promotion and disease prevention (38, 39, 41-43, 47, 51)	Knowledge/Behaviour	7
		Demonstrate knowledge of the social and cultural importance of food, including awareness of food consumption trends and current nutrition recommendations (21, 38, 39, 41, 43, 51)	Knowledge/Behaviour	6
		Demonstrate knowledge of nutrition-related causes of mortality and morbidity in the population (21, 38, 51)	Knowledge/Behaviour	3
		Demonstrate knowledge of the principles of public health nutrition, including strategies to reduce the burden of disease (39, 48)	Knowledge/Behaviour	2
		Describe food-borne illnesses and outline the process of reporting and investigating outbreaks of these illnesses (39)	Knowledge/Behaviour	1
Communication n=7 (64%)	Nutrition counselling skills	Demonstrate the ability to effectively provide nutrition education and counselling (21, 38, 39, 43, 47, 50)	Skill	6
		Demonstrate sensitivity to the social, cultural, emotional, and psychological factors that may affect an individual's nutrition behavior and health status (39)	Attitude/Value	2
Working as a team n=7 (64%)	The Multidisciplinary Team Approach to nutrition care	Demonstrate the ability to work effectively in a multidisciplinary team to deliver nutrition care, including the ability to refer onwards (21, 39, 41, 47, 49)	Skill	5
		Demonstrate knowledge of the role of other health professionals and community services in the multidisciplinary approach to nutrition care (39, 43, 51)	Knowledge/Behaviour	3
Professional Practice n=3 (27%)	Critical thinking	Demonstrate ability to think critically including the ability to interpret nutrition evidence and apply appropriately in clinical practice (21, 39, 41, 43, 50)	Skill	3
	Ethics	Demonstrate the ability to consider and apply principles of ethics related to nutritional management (38, 39, 41)	Attitude/Value	2

		Demonstrate a commitment to promote sound nutritional decision-making and appropriate levels of physical activity for all patients regardless of health status (39)	Attitude/Value	1

283 [a]**Number of articles which include this competency**

Level of medical education:

All 11 articles specified the level of medical education where there would be an expectation to teach and achieve the nutrition competencies. Five articles included nutrition competencies for undergraduate and graduate (entry-level) medical education. Three of the 11 articles stipulated use by primary care providers and one paper included competencies for family practice residents. The remaining two articles merely specified use by "practicing physicians".

Summary of concepts

A summary nutrition competency framework, adapted from Hughes et al. (2012) (20) and informed by the Dreyfus model of skill acquisition, the framework for clinical competency assessment outlined in Miller (1990) and the Knowledge to Action Cycle as described by Graham and colleagues (2006) (20, 27, 28, 52, 53) is presented based on the competencies in the literature (Figure 2 or Table 4). This provides a preliminary model for a nutrition competency framework for medicine, which can be further investigated in subsequent research. In this framework, categories of competency units are delineated into four different tiers to represent hierarchies of competency acquisition and assessment. At the base of the matrix are enabling and critical competencies (know and know how) which underpin higher level nutrition practice behaviours. At a foundational level, the Dunning-Kruger Effect indicates that individuals may be 'unconsciously unskilled' (54). The proposed framework also includes common, cross-cutting attributes identified in this review. Cross-cutting competencies delineate the professionalism required for effective, collaborative and safe practice and improve the transferability of the competency framework across health disciplines (20). Top-level practice competencies are defined by Hughes et al. (2012) as "higher order composite behaviours" which are required to "perform complex practice behaviours" which underpin core functions of the profession (20). Practice competencies involve behavioural performance (showing how and doing) and it is hoped the inclusion of these competencies bridges the gap between cognitive competencies and translation in practice (20).

Insert Figure 2 here OR

Table 4. Proposed conceptual nutrition competency framework for medicine

PRACTICE (DOES)	Assessment of nutritional health including the ability to calculate energy expenditure, nutrition requirements and body composition	Select and prescribe dietary strategies in the prevention and treatment of disease	Monitor nutrition status and modify dietary recommendations as needed	Effectively provide nutrition education and counselling	Work effectively in a multidisciplinary team to deliver nutrition care, including the ability to refer onwards	
CROSS-CUTTING (SHOWS HOW)	***Clinical Practice***	***Health Promotion and Disease Prevention***	***Communication***	***Working as a Team***	***Professional Practice***	
CRITICAL (KNOWS HOW)	Evidence-based dietary strategies for the prevention and treatment of disease	Knowledge of possible drug-nutrient interactions and prescribe accordingly	Think critically including the ability to interpret nutrition evidence and apply appropriately in clinical practice	Consider and apply principles of ethics related to nutritional management	Commitment to promote sound nutritional decision-making and appropriate levels of physical activity for all patients regardless of health status	Awareness of their own personal health and nutrition
ENABLING (KNOWS)	Knowledge of the functions of essential nutrients	Nutritional content of food including the major dietary sources of macronutrients and micronutrients	Nutrition applied to different stages of the life cycle	Describe food-borne illnesses and outline the process of reporting and investigating outbreaks of these illnesses	An understanding of how disease and its management can affect nutritional status	Awareness of the social and cultural importance of food, including food consumption trends and current nutrition recommendations
	Basic scientific principles of human nutrition	The role of nutrition in health promotion and disease prevention	Breastfeeding and complementary feeding practices	Food allergies and intolerances	Nutrition-related causes of mortality and morbidity in the population	Public health nutrition, including strategies to reduce the burden of disease	The role of other health professionals and community services in the multidisciplinary approach to nutrition

DISCUSSION

There is currently no consensus on nutrition competencies relevant for medical education. This review provides a critical synthesis of published nutrition competencies for medical education and practice internationally. This review identified five common themes across nutrition competencies which add to existing literature related to medical nutrition education. Twenty-five unique nutrition competencies for medical education were identified from 11 articles.

The five common themes across nutrition competencies for medicine, were clinical practice, health promotion and disease prevention, communication, working as a team and professional practice. The latter three, while referring to nutrition, highlighting generic skills that are required to be applied across all aspects of medical care. This is congruent with core competencies and individual roles in existing medical frameworks, such as the CanMEDS Physician Competency Framework, the Accreditation Council for Graduate Medical Education (ACGME) core competencies, the General Medical Council (GMC) Outcomes for graduates, the Australian Medical Council Limited (AMC) Graduate Outcome Statements and the Royal Australasian College of Physicians (RACP) Professional Practice Framework (44, 55-58). For example, the CanMEDS Physician Competency Framework, one of the most globally recognized health care profession competency frameworks articulates a number of intrinsic roles which reflect key themes identified in this review, such as the Communicator, Collaborator and Health Advocate.

Generic themes such as those identified in this review can provide leverage in educational reform, by aligning incentives to facilitate synergy across health care professions (59). For example, a multidisciplinary team (MDT – identified as "working as a team" in this review) approach to nutrition care has been shown to provide high quality, cost-effective nutrition outcomes (60, 61). However, there is a disconnect between the university education environment, which is generally not interdisciplinary, and the practice environment, which increasingly requires collaborative skills (59). Furthermore, communication and collaboration are key aspects of the iterative process of knowledge translation, including the ability to exchange information to overcome barriers to implementation. Communication and collaboration (teamwork) were also common themes identified by this review. Optimized knowledge translation has been shown to improve the quality of evidence-based nutrition care and strengthen the health care system, as summarised by the Knowledge to Action Cycle (53).

Not only does this cross-over between medical and nutrition competencies highlight the lateral nature of nutrition as a cognate scientific discipline, but it also provides merit to opportunity for the vertical integration of nutrition competencies into existing medical education. Rather than an isolated concept with a distinct set of competencies, existing medical spiral curricula could be enhanced by applying existing medical competencies to a nutrition context. Deen (2006) illustrated this by successfully mapping the Curriculum Committee of the National Academic Award (NAA) learning objectives to the ACGME competencies for competency-based resident evaluation (62). This reiterates the relevance of nutrition as a core facet of clinical practice without necessarily adding time to curricula. Namely, vertical integration of nutrition competencies into medical education is particularly relevant in a crowded curriculum, and is a key element of a successful integrated medical nutrition curriculum, shown to improve medical students' perceptions of nutrition as part of total patient care (63, 64). However, there is a need to first build consensus on nutrition competencies for medical education

The majority of the medical nutrition competencies identified in this review were knowledge-based, while less than 30% of nutrition competencies were skill-based and only four competencies were attitude-based (Table 3). While knowledge-based (enabling) competencies are essential to interpret new concepts in nutrition and underpin higher order (practice) competencies, skill-based competencies are relevant to clinical practice, which requires the complex and judicial application of knowledge, technical skills, clinical reasoning, values and reflection under varied circumstances (36). This is in line with the experience of medical graduates and practising physicians, who do not feel comfortable or adequately prepared to provide nutrition counselling to their patients (10, 16, 65, 66). In order to overcome these barriers, Adams et al., (2010) and Lindsley et al., (2017) emphasise the need for "skill-centred nutrition training" (67). A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals, reports that educational interventions which led to improvements in the delivery of nutrition care focused on skills and attitudes rather than just knowledge (68). Skill-based nutrition training has been shown to improve medical students' nutrition knowledge and confidence in lifestyle counselling (69).

While competency frameworks provide an architectural blueprint for constructing educational programmes, the centrality of valid assessment methods to support the life-long journey of competency development cannot be overlooked (19). Increasing the weighting of a topic in

assessment has been shown to enhance medical students' reported motivation to learn about the topic (70). Furthermore, regular and repeated assessment can improve knowledge retention in medical students (71, 72). This is particularly important given that despite initial high interest in nutrition, interest in and perception of the importance of nutrition may decline during time in medical school (73). Earlier research highlights the effectiveness of the Objective Structured Clinical Exam (OSCE) in evaluating the ability to synthesise and translate knowledge to clinical practice (64). Miller (1990) also emphasises the role of skill-based assessment methods such as the OSCE in the appraisal of technical and clinical competence (74). Problem-based learning tutorials, culinary skills training and clinical case presentations have also been shown to promote active learning and lead to significant changes in participants' knowledge, personal health habits, confidence to provide dietary counselling and ability to nutritionally manage malnutrition (68). A combination of innovative learning strategies is required to support the development of clinical competence. Educational strategies and assessment methods which improve nutrition care competencies, such as problem-based learning and the OSCE, are already widely used methods in medical education (75). Therefore, the application of existing learning to a nutrition context, such as a nutrition OSCE, may lead to improvements in competency to provide nutrition care in future practice. There is currently no consensus on the required nutrition competencies for medicine, which presents a further barrier to the integration of nutrition in medical education (16). The nutrition competencies identified in this review provide a potential benchmark for the nutrition knowledge, skills and attitudes to be included in curricula (Table 3). However, given the lack of consensus on relevant nutrition competencies, commitment of individual institutions to compulsory nutrition education is insufficient and regulation is required. The 2019 report 'Doctoring Our Diet' recommends policy levers to include nutrition in U.S. medical training, such as government investment to provide financial incentive for the inclusion of nutrition in medical training, amending accreditation standards to mandate requirements for nutrition education, increasing representation of nutrition in step and board-examinations and compulsory nutrition training in continuing medical education (17).

STRENGTHS AND LIMITATIONS

This review offers a critical and timely synthesis of medical nutrition competencies and a conceptual nutrition competency framework. As an integrative review, this framework might be considered a candidate theory for further review and development. However, this review

also needs to be considered in the context of its limitations. While the search strategy used included terms previously used to identify competency frameworks, others may exist and therefore some studies may not have been captured. We acknowledge there may be some bias in the conduct of the review in that only one author was involved in extraction of data. It is recognized that the characteristics of included publications is skewed towards those published in the USA (and English language) and that this may have biased our findings. However, it is relevant to note that there are a greater number of medical education facilities in the USA than other countries included such as Australia, New Zealand and Sweden (76). The majority (6/7) of the included studies were published in developed countries; this may have implications on the generalisability of the proposed nutrition competency framework. We used the Dreyfus model of skill acquisition, Miller's hierarchy for the assessment of clinical competence and the Knowledge to Action Cycle (20, 27, 28, 52, 53) to frame this work, and acknowledge that other frameworks may also be useful in this context. For example, the frameworks used may not consider elements of cognitive aptitude such as diagnostic reasoning.

CONCLUSION

This review identified five common, cross-cutting themes across nutrition competencies for medicine: 1) clinical practice, 2) health promotion and disease prevention, 3) communication, 4) working as a team and 5) professional practice. This review also identified twenty-five nutrition competencies for medicine, the majority of which were knowledge-based. The most common nutrition competencies were related to nutrition assessment, dietary interventions for the prevention and treatment of disease, the role of nutrition in health promotion and disease prevention and knowledge of the social and cultural importance of food. This review recommends vertical integration of nutrition competencies into existing medical education based on key, cross-cutting themes, and increased opportunities to engage in relevant, skill-based nutrition training.

Acknowledgements: We would like to thank Isla Kuhn, Medical Librarian at the University of Cambridge for her invaluable input to the search strategy.

Contributors: BL, EB, KM and SR contributed to the design of the review. BL did the literature search, performed data analysis and drafted the manuscript. EB contributed to data extraction. All authors contributed to revision of the manuscript and approval of the final manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. Patients and/or the public were not involved in this study.

Funding: This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests: None declared.

Patient consent for publication: Not required.

Data availability statement: There are no data in this work.

Figure 2. Proposed conceptual nutrition competency framework for medicine

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Figure 1. PRISMA flow diagram for identification of articles related to nutrition competencies for medicine.

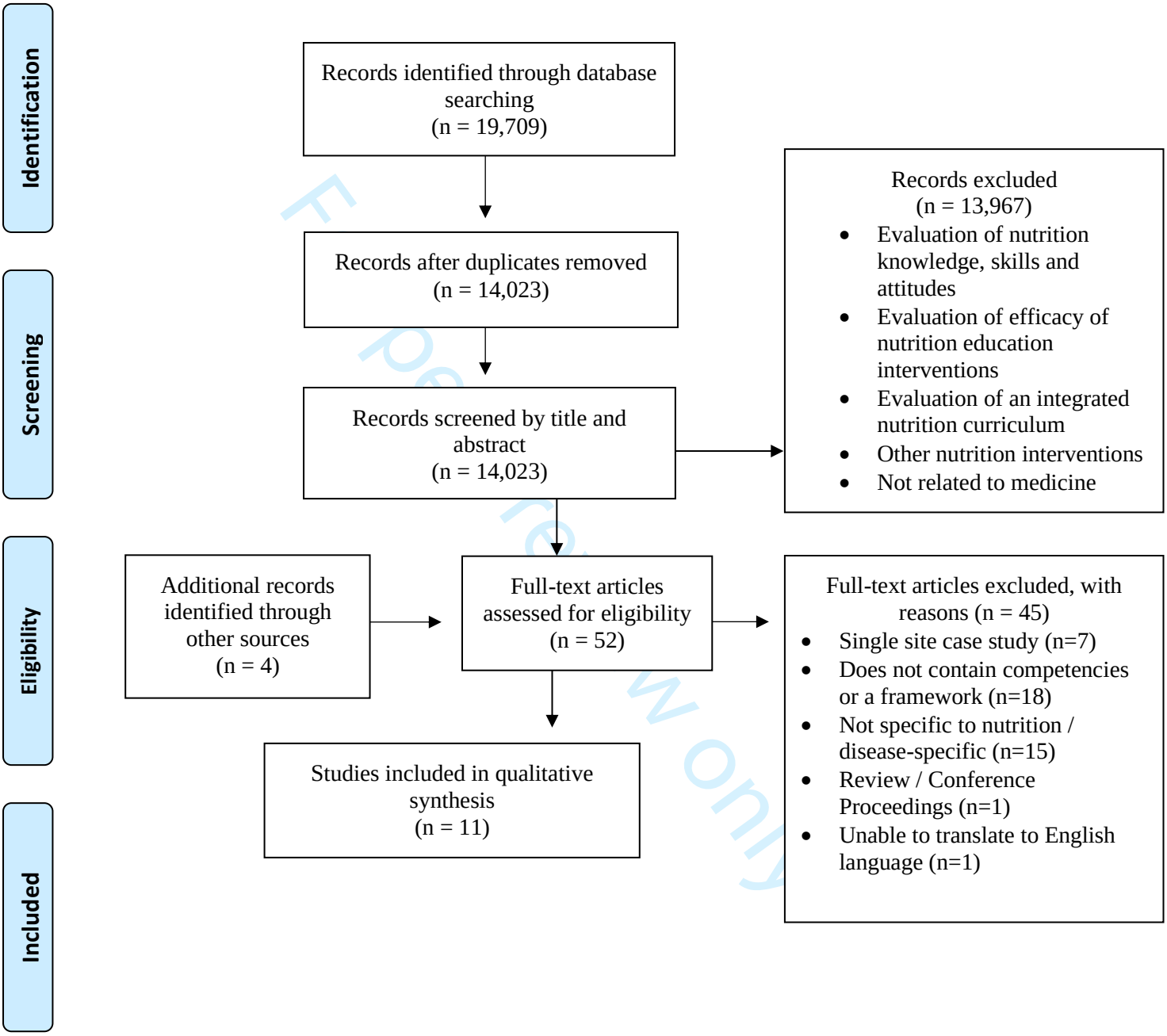

Figure 2. Proposed conceptual nutrition competency framework for medicine

PRACTICE (DOES)	Assessment: energy expenditure, nutritional requirements, body composition	Select/prescribe dietary strategies: prevention and treatment	Monitor nutrition status/modify dietary recommendations	Effectively provide nutrition education and counselling	Work effectively in a multidisciplinary team/refer as required	
CROSS-CUTTING (SHOWS HOW)	***Clinical Practice***	***Health Promotion and Disease Prevention***	***Communication***	***Working as a Team***	***Professional Practice***	
CRITICAL (KNOWS HOW)	Evidence-based dietary strategies: prevention and treatment	Drug-nutrient interactions and prescribe accordingly	Think critically: interpret nutrition evidence, apply appropriately	Apply principles of ethics related to nutritional management	Promote sound nutritional decision-making and appropriate physical activity	Awareness of personal health and nutrition
ENABLING (KNOWS)	Knowledge of functions of essential nutrients	Nutritional content of food including the dietary sources of macro/micronutrients	Nutrition applied to the life cycle	Describe food-borne illnesses; outline process of reporting & investigating outbreaks	Understanding of how disease/management affects nutritional status	Awareness of social & cultural importance of food; consumption trends; dietary guidelines
	Basic scientific principles of human nutrition	Role of nutrition in health promotion/ disease prevention	Breastfeeding and complementary feeding practices	Food allergies and intolerances	Nutrition-related causes of mortality and morbidity	Public health nutrition, including strategies to reduce burden of disease	Roles of health professionals/ community services in multidisciplinary approach to nutrition

Supplementary Materials 1 – Search Strategy

Data base	Search terms	Results
CINAHL Plus with Full Text	(((“doctor*” OR (“physicians+”)) OR (“medical student*”) OR ((“students, medical”) OR “(medic* OR doctor* OR clinical*) N2 student*”) OR ((“general practitioner” OR family doctor* OR family physician*”) OR (“physicians, family”)) OR ((“interns and residents”) OR “medical N3 (specialist* OR intern* OR resident*))” OR (specialist registrar*) OR (clinical specialist*) OR ((“education, medical+”) OR “medical education” OR (“education, medical, continuing”)) OR (“undergraduate medical education”) OR (“postgraduate medical education”) OR ((“nutrition education) OR “nutrition education” OR (“nutritional physiology+”)) OR (“medical nutrition education”) AND ((“nutrition”) OR “nutrition*” OR (“public health nutrition”) OR (“nutrition services+”) OR (“nutrition policy+”)) OR ((“diet”) OR “diet*”) OR ((“life style+”) OR “lifestyle”) AND ((competen*) OR ((“clinical competence+”) OR “clinical competen*”) OR ((“education, competency-based”) OR “competency-based education”) OR ((“curriculum+”) OR “curricul*”) OR (“competency framework*” OR (“professional competence+”)) OR (competency standard*)))	2650
Embase	(((doctor*) OR (physician* OR ‘physician’/exp) OR (‘hospital physician’/exp) OR (medical student* OR ‘medical student’/exp) OR ((medic* OR doctor* OR clinical*) NEAR/2 student*) OR (medical NEAR/3 (specialist* OR intern* OR resident*)) OR (specialist registrar* OR ‘medical specialist’/exp) OR (clinical specialist*) OR (medical education OR ‘medical education’/exp) OR (undergraduate medical education) OR (graduate medical education OR ‘residency education’/exp) OR (nutrition education OR ‘nutrition education’/exp OR ‘health education’/exp) OR (medical nutrition education)) AND ((nutrition* OR ‘nutrition’/exp OR ‘nutrition service’/exp) OR (diet* OR ‘diet’/exp) OR (lifestyle* OR ‘lifestyle’/exp OR ‘lifestyle modification’/exp)) AND ((competen* OR ‘competence’/exp) OR (clinical competen* OR ‘clinical competence’/exp) OR (curricul* OR ‘curriculum’/exp OR ‘medical school’/exp) OR (competency framework* OR ‘professional competence’/exp) OR (competency standard*)))	7695
Global Health	(((doctor* OR physician+) OR (medical student* OR medical students) OR ((medic* OR doctor* OR clinical*) N2 student*) OR ((general practitioner* OR gp* OR family doctor* OR family physician*) OR general practitioners) OR (medical N3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR (clinical specialist*) OR (medical	1280

	education OR medical education+) OR (undergraduate medical education OR medical schools) OR (graduate medical education OR continuing education OR medicine+) OR (nutrition education) OR (medical nutrition education)) AND ((nutrition* OR nutrition+ OR nutrition programmes OR nutrition physiology OR nutrition planning OR nutrition information OR clinical nutrition OR community nutrition OR nutritional support OR nutritional intervention OR nutritional assessment) OR (diet* OR diet OR diet counselling OR diet planning) OR (lifestyle* OR lifestyle)) AND ((competen* OR professional competence) OR (clinical competen*) OR (competency-based education) OR (curricul* OR curriculum+ OR curriculum guides) OR (competency framework*) OR (competency standard*)))	
Medline	((("doctor*") OR ("physician*") OR ((medic* OR doctor* OR clinical*) NEAR/2 "student*") OR ("medical student*") OR (("general practitioner* OR gp* OR family doctor* OR family physician*") OR "physicians, family" OR "general practitioners") OR (("medical NEAR/3 (specialist* OR intern* OR resident*)" OR "internship and residency" OR "internal medicine+") OR ("specialist registrar*") OR ("clinical specialist*") OR ("medical education" OR "education, medical+" OR "education, medical, undergraduate+" OR "education, medical, continuing" OR "education, premedical") OR ("postgraduate medical education") OR ("nutrition education" OR "nutritional sciences+")) AND ((competen*) OR ("competency-based education" OR "clinical competence" OR "professional competence+") OR ("curricul*" OR "curriculum+") OR ("competency framework*) OR ("competency standard*)) AND ("nutrition*" OR "nutrition therapy+") OR ("diet*" OR "diet+" OR "diet therapy+") OR ("lifestyle*" OR "life style+")))	3605
Scopus	(((doctor* OR ((medic* OR doctor* OR clinical*) W/2 student*) OR ("medical student") OR ("general practitioner*" OR gp* OR "family doctor*" OR "family physician*") OR (medical W/3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR ("clinical specialist*") OR ("medical education") OR ("undergraduate medical education") OR ("postgraduate medical education")) AND ((nutrition*) OR (diet*) OR (lifestyle* OR "life style")) AND ((competen*) OR ("clinical competen*") OR ("competency-based education") OR (curricul*) OR ("competency framework") OR ("competency standard*")))	2382
Web of Science	(((doctor*) OR (physician*) OR (medical student*) OR (student* NEAR/2 (medic* OR doctor* OR clinical*)) OR (general practitioner* OR gp OR family doctor* OR family physician*) OR (medical NEAR/3 (specialist* OR intern* OR resident*)) OR (specialist registrar*) OR (clinical	2097

	specialist*) OR (medical education) OR (undergraduate medical education) OR (postgraduate medical education) OR (nutrition education) OR (medical nutrition education)) AND ((nutrition*) OR (diet*) OR (lifestyle* OR life style)) AND ((competen*) OR (clinical competen*) OR (competency-based education) OR (curricul*) OR (competency framework*) OR (professional competen*) OR (competency standard*)))	
Total yield from all databases		**19709**

Supplementary Materials 2 – List of excluded studies along with reasons for exclusion

Full-text articles excluded, with reasons (n=45)

- Single site case study (n=7)
- Does not contain competencies or a framework (n=18)
- Not specific to nutrition / disease-specific (n=15)
- Review / Conference Proceedings (n=1)
- Unable to translate to English language (n=1)

Study	Reason for Exclusion
Adams et al., 2010	Does not contain competencies or a framework
Akner & Vessby, 1997	Does not contain competencies or a framework
Al-Nimr et al., 2019	Single site case study (Not formally adopted or endorsed)
Asp et al., 1995	Does not contain competencies or a framework
Aspry et al., 2018	Framework not specific to nutrition (Competencies for ASCVD prevention)
Bairey Merz et al., 2009	Framework not specific to nutrition (Competencies specific to the prevention of cardiovascular disease)
Bakemeier et al., 1989	Framework not specific to nutrition (Nutrition and cancer education objectives)
Ball et al., 2010	Single site case study (Not formally adopted or endorsed)
Brodribb et al., 2012	Framework not specific to nutrition (Competencies specific to breastfeeding)
Chamberlain et al., 1989	Does not contain competencies or a framework
Cooksey et al., 2000	Does not contain competencies or a framework
Cresci et al., 2019	Does not include competencies or a framework
Committee of the Nutrition Academic Award Program, 2002	Does not contain competencies or a framework
Dahl, 2006	Does not include competencies or a framework
Edwards & Rosenfeld, 2006	Single site case study (Not formally adopted or endorsed)
Gallagher et al., 1979	Does not contain competencies or a framework
Hark et al., 2000	Single site case study (Not formally adopted or endorsed)
Heimburger, 2002	Does not contain competencies or a framework
Heimburger, 2006	Does not contain competencies or a framework
Hivert et al., 2016	Does not contain competencies or a framework
Huang et al., 2009	Framework not specific to nutrition (Health and obesity: prevention and education curriculum)
Jackson, 2001	Review article
Jensen & Hessov, 1991	Does not contain competencies or a framework
Kaye et al., 2018	Does not contain competencies or a framework
Kelly et al., 2019	Framework not specific to nutrition (Competencies for lifestyle medicine intensivists)

Kligler et al., 2004	Framework not specific to nutrition (Competencies in integrative medicine)
Kushner et al., 2019	Framework not specific to nutrition (Obesity competencies)
Lianov et al., 2010	Framework not specific to nutrition (Physician competencies for prescribing lifestyle medicine)
Lin et al., 1999	Unable to translate to English from Chinese
Maiburg et al., 2004	Single site case study (Not formally adopted or endorsed)
Milla, 2002	Framework not specific to nutrition (European training syllabus in paediatric gastroenterology, hepatology and nutrition)
Mularski et al., 1997	Does not contain competencies or a framework
Mulder et al., 2016	Single site case study (Not formally adopted or endorsed)
Powell-Tuck et al., 1997	Does not contain competencies or a framework (course evaluation)
Ray et al., 2010	Does not contain competencies or a framework
Rock et al., 1995	Does not contain competencies or a framework
Rudolph et al., 1999	Framework not specific to nutrition (NASPGN guidelines for training in paediatric gastroenterology)
Ryen et al., 2003	Framework not specific to nutrition (Gastroenterology core curriculum)
Scolapio et al., 2008	Does not contain competencies or a framework
Somannavar, 2012	Single site case study (Not formally adopted or endorsed)
The Gastroenterology Leadership Council, 1996	Framework not specific to nutrition (Gastroenterology core curriculum)
Trilk et al., 2019	Framework not specific to nutrition (Lifestyle medicine curriculum)
Weinsier et al., 1989	Does not contain competencies or a framework (Priority rankings for nutrition topics to be included in curriculum)
Winick, 1993	Does not contain competencies or a framework
Withers et al., 2019	Framework not specific to nutrition (Core competencies in global health training)