BMJ Open

A realist synthesis of educational interventions to improve nutrition care competencies and delivery of nutrition care by doctors and other healthcare professionals

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2015-010084
Article Type:	Research
Date Submitted by the Author:	23-Sep-2015
Complete List of Authors:	Mogre, Victor; UNIVERSITY FOR DEVELOPMENT STUDIES, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences Scherpbier, Albert; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Stevens, Fred; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Aryee, Paul ; University for Development Studies,, Department of Community Nutrition, School of Allied Health Sciences Cherry, Mary; University of Liverpool, Department of Health Services Research, Institute of Psychology, Health and Society Dornan, Timothy; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism, Patient-centred medicine, Public health, Qualitative research, Research methods
Keywords:	EDUCATION & TRAINING (see Medical Education & Training), Public health < INFECTIOUS DISEASES, Nutrition < TROPICAL MEDICINE

A realist synthesis of educational interventions to improve nutrition care competencies and delivery of nutrition care by doctors and other healthcare professionals

Victor Mogre*[1, 2], Albert J.J.A Scherpbier[2], Fred Stevens[2], Paul Aryee[3], Mary Gemma Cherry[4] & Tim Dornan[2]

[1]Victor Mogre
Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, School of Medicine and Health Sciences, University for Development Studies, Ghana
[2]School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[2]Albert J.J. A. Scherpbier
School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[2]Fred Stevens
School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[1]Paul Aryee
Department of Community Nutrition, School of Allied Health Sciences, University for Development Studies, Ghana

M.G. Cherry
Department of Health Services Research, Institute of Psychology, Health and Society. University of Liverpool, United Kingdom/

[2]Timothy Dornan
School of Health Professions Education, Faculty of Health, Medicine and Life Sciences
Maastricht University, The Netherlands

*__Corresponding author:__ Victor Mogre, Department of Education and Innovative Learning, School of Medicine and Health Sciences, University for Development Studies, Box, TL 1883, Tamale.
Email: vmogre@uds.edu.gh

Key words: Realist review; nutrition; Educational interventions; medical students and doctors

Word count: 5562, four tables, and two figures

Abstract

Objective: What sort of educational interventions work, how, for whom, why and in what circumstances to improve the delivery of nutrition care by doctors and other healthcare professionals?

Design: Realist synthesis following a published protocol and reported following Realist and Meta-narrative Evidence Synthesis: Evolving Standards (RAMESES) guidelines, seeking to gain insight into and to explain the interaction between the context of interventions, the mechanisms and outcomes they generate. The search strategy was to search nine leading bibliographic databases using a search syntax, which optimized sensitivity to relevant publications. The method of selection was to include all study designs. Articles identified by the search were appraised for their ability to answer the review question. Data were analysed by identifying relationships between contexts, mechanisms, and outcomes (CMO) and entering them into a spreadsheet configured for the purpose. The final synthesis identified commonalities within the CMO configurations.

Results: Data were extracted from 37 studies, over half of which originated from the US. Characteristics of interventions that worked to improve the delivery of nutrition care included placing emphasis on improving skills and attitudes instead of cognitive outcomes, incorporating opportunities for modelling nutrition care delivery by superiors, removing systemic barriers, providing participants with local, practical relevant tools and messages and incorporating non-traditional, innovative teaching strategies. Embedded in a context of both future and practicing healthcare professionals as well as in both developed and developing countries these yielded outcomes through mechanisms such as feeling competent, feeling confident/self-efficacious and comfortable to deliver nutrition care, perceived reduction in systemic barriers and feeling accepted and recognised to deliver nutrition care.

Conclusion: The findings of this review indicate characteristics and conditions of interventions that are successful in improving the delivery of nutrition care by doctors and other healthcare professionals, and may inform the design of future educational interventions.

Strengths and Limitations of this study

1. To our knowledge, this review represents the first use of realist synthesis in nutrition research, contributing to an emerging field in systematic review.
2. The focus of this review of evaluating characteristics and conditions of educational interventions to improve the delivery of nutrition care has important implications for policy makers, researchers, health professions educators, and course developers.
3. Our review was affected by publication bias, as none of the included studies reported a failed educational intervention, limiting the opportunity to get evidence that cuts across interventions.
4. We note that until our conceptual model is tested and refined in the real world, we consider it to be an indefinite candidate theory, presenting elements worth considering by those concerned with the design, implementation and evaluation of educational interventions to improve the delivery of nutrition care in the context of both future and practicing healthcare professionals.
5. The included primary studies may or may not be indicative of "real world practices" of future and practicing doctors and other healthcare professionals due to the limited availability of studies employing methodological approaches that are able to measure and critically analyse the delivery of nutrition care.

Protocol

Published at http://www.systematicreviewsjournal.com/content/pdf/2046-4053-3-148.pdf

Introduction

Nutrition is an important component of healthcare and plays a critical role in the prevention and treatment of leading causes of disease burden and death globally, such as cardiovascular and cerebrovascular disease and diabetes mellitus [1-3]. In sub-Saharan Africa malnutrition is responsible for morbidity and mortality in children [4].

Even though several landmarks reports [5 6] have identified the delivery of nutrition care as one of the core responsibilities of doctors as well as the positive influence of doctors' nutrition counselling on clinical outcomes, doctors and other healthcare professionals more often than not miss opportunities to advise diet and health[7 8]. Lack of knowledge [9], skills and confidence in providing nutrition care [10 11] as well as negative attitudes towards delivery of nutrition care and low clinical outcome expectancy[12] have been identified as barriers to delivery of nutrition care. In addition to these doctor-related factors, several system-related factors have been attributed to doctors 'delivery of nutrition care such as lack of time, lack of supportive office, lack of payment and referral sources and materials, lack of adequate training in school [13].

In response to this situation, several educational interventions have been designed and implemented to improve the delivery of nutrition care. These interventions have yielded low and variable successes [14-16]. Hence, appropriate interventions are still needed to change healthcare professionals' nutrition practice behaviour [14-16]. Factors relating to behavioural and the social-environment have been reported to mediate or forestall nutrition care competency and delivery by health care professionals [17 18]. It is imperative to identify principal components of effective educational interventions and the processes therein to improve the delivery of nutrition care.

Even though evidence is available regarding the effects of educational interventions on the nutrition knowledge, counselling skills, nutrition practice behaviour and management of undernutrition, only one secondary research investigation has summarized evidence for policy [19]. In that review, authors concluded that in-service nutrition training of health workers improved their nutrition knowledge, nutrition and general counselling skills, and undernutrition management skills. This review followed a traditional systematic review process and considered only in-service nutrition training programs. Furthermore, authors identified heterogeneity as a limitation to their review. They noted that the included studies had heterogeneous study designs and measurements used for outcome variables as well as differences in the competence, experience, and cadres of participating health workers. Authors did not recognize and account for the complexity of the interactions within such educational interventions, probably due to the limitations of a traditional systematic review.

To cater for this heterogeneity and complexity, we conceptualized educational interventions to improve the delivery of nutrition care as complex and hence adopted a realist approach. As noted in our review protocol published elsewhere [20], educational interventions to improve the delivery of nutrition care involves multiple actors (teachers, learners, patients, health care providers, etc.) operating at different levels, the artefacts they use and the material environments in which they work [21]. We assumed that these components operate in a non-linear fashion to yield context-dependent outcomes. Uniquely, realist synthesis brings to bear "what is it about this intervention that works for whom in what circumstances" and hence the most appropriate methodology to adopt for this review[22].

The purpose of this realist review is to determine what sort of educational interventions work, how, for whom, why and in what circumstances to improve the delivery of nutrition care by doctors and other healthcare professionals.

Methods

Alteration from protocol

The review question above is broader than in the published protocol [20]because the search showed important findings from research in other professionals, which the team felt could make a valuable contribution to the review.

Search strategy

Identifying primary studies

VM developed a set of search terms; scoped the search on two databases; reviewed the articles identified by the search; concluded there was no need to refine the search terms and proceeded to the main search. In June 2014, VM undertook a search of the nine data bases including Medline, CINAHL, ERIC, EMBASE, PsyINFO, Sociological abstracts, Web of Science, Google Scholar and Science Direct. Using a variety of combinations of free text, key words used to search the databases included educational interventions; capacity building; medical students; doctors, healthcare professionals, curriculum; competencies; nutrition; knowledge; attitudes; self-efficacy; behaviours; training. Studies published within the last two decades (January 1994 to June 2014), peer reviewed and published in English were included. Terms were joined using the Boolean operators "OR" and "AND". In order to cater for different uses of terms, truncation was employed. The search strategy is available from the authors on request.

For the purposes of this study and as defined in our published protocol [20], nutrition care competency was referred to as the capability to apply or use nutrition knowledge and skills/abilities needed to deliver nutrition care to patients in a defined work setting. In this review, nutrition care included nutrition screening/assessment (e.g. food/nutrition history, biochemical data, medical tests and procedures, body mass index, etc.), nutrition diagnosis, nutrition intervention (education and counselling), nutrition monitoring and evaluation.

Inclusion criteria

1. **Study participants:** Those studies that had medical students, doctors and other healthcare professionals (e.g. nurses, nutritionists, etc) as participants were included.
2. **Focus of intervention:** Studies that focused on developing nutrition care competencies of participants. Studies that dealt with improving any aspect of nutrition practice behaviour.
3. **Study design:** All study designs encompassing positivist, interpretist and action research paradigms were included.
4. **Context of intervention:** For the purposes of this review, settings included practice at the hospitals and during training at medical school and other health professionals. Studies conducted in either of these settings or both were included.
5. **Language and geography:** The search covered all languages and geographical locations but only articles reported in English were included into the review.
6. **Year of publication:** All papers published from Jan 1994 – June 2014 were included in the search. The review team's knowledge of the literature informed the choice of 1994.

Exclusion criteria

Those studies that had only dietitians and/or nutritionists as learners were excluded as the delivery of nutrition is their core responsibility. Conference proceedings, opinion pieces, case studies and abstracts were excluded

Selection process

Using the identified keywords the first search yielded 4500 hits. After eliminating duplicates VM did the first stage of screening using titles to select 357 studies. Abstracts of these studies were obtained and evaluated by VM, TD and MGC to ascertain whether the study was related to improving nutrition care competencies and delivery of nutrition care. At a face-to-face discussion, the results of each of the reviewers were compared and a kappa statistic of 0.9 was obtained indicating a high level of agreement among the reviewers. The few differences were resolved by consensus. This final evaluation resulted in 74 studies. The full text of 52 studies were obtained and downloaded into the Mendeley reference manager as the full texts of 22 studies were unavailable due to poor indexing and copyright policies. The reading of the reference list to identify more studies resulted in the inclusion of 11 studies yielding 63 studies. Figure 1 shows the flow chart of the search and selection processes. Update of the literature search was done prior to data analysis (due to a lapse of about 6 months between the initial search and data analysis). Email alerts from journals and RSS feeds from databases were set to ensure that new papers are identified as soon as they become available.

=Insert figure 1=

Quality assessment

In realist review, part (s) of the study could be included provided the methods employed for such data are robust to support the judgement accorded it [23]. VM undertook an initial reading and re-reading of the full text of the 63 studies and selected 46 studies. Reasons for exclusion were unavailability of evaluation or outcome data; not being about improvement in nutrition care competencies and being systematic reviews. Moving to another stage of quality assessment, the 46 studies were shared among AS, TD, FS and MGC, who read and re-read the full text of their respective papers, resulting in the exclusion of 9 studies, remaining 37 studies which were included into the analysis. In both stages reviewers' judgements of the studies were based on: trustworthiness of data from studies; appropriateness of the study design and data collection tools vis-à-vis outcomes reported; strength of the evidence with regards to sample sizes; and relevance to our program theory. Reasons were noted for inclusion and exclusion of studies and if there were doubts regarding the inclusion or exclusion of a study, discussions were held between VM and the reviewer concerned. If unresolved other members of the team were consulted (either TD or AS).

Data extraction, analysis and synthesis

For the purposes of data extraction, we created a Microsoft excel spreadsheet informed by previously reported realist reviews [21]. The data domains covered included the following:

- Study design, sample size, outcome data
- Educational level of study participants (students and practicing doctor/healthcare professional)
- Development processes of course material
- Topics covered

- Methods of teaching and learning
- Evaluation methods including data collection tools
- Intervention type (workshops, CMEs)
- Duration of intervention
- Context of intervention
- Mechanisms generated
- Expected learning outcomes
- Impact of intervention on clinical outcomes if any
- Any theories or mechanisms postulated by author(s) explaining the success or failure of the intervention

We read and re-read all the 37 included studies capturing relevant data, identifying the context, mechanism and outcomes and the interactions therein for each study as well as the theory informing each intervention (in realist review, interventions are theories). Each intervention has a theory of how it should work either explicitly or implicit. We read, discussed and reflected through all that has been identified (context, mechanism and outcome) for each study (sometimes extracts of text from the included studies) identifying common themes across different studies. Using an interpretative and narrative approach initial conclusions and synthesis of key findings were discussed and used to either refute or refine our candidate theories.

Results

General characteristics of the studies

Table 1 provides a summary of all the included studies. Out of the 37 studies reviewed, 21 (57%) came from the USA; seven (19%) from Europe; four each from South America (all from Brazil) and Asia, and only one study from Africa (South Africa). From the 37 studies, 4306 participants (median = 66.0; interquartile range: 38.0, 163.0) participated in the interventions. There was a tendency towards larger numbers of participants in interventions that targeted healthcare professionals (median = 54.0; interquartile range (32.0, 152.0) than in interventions that targeted students (median = 98; interquartile range 46.0, 163.0)).

The included studies employed varied study designs and data collection tools (shown in table 2). Majority (70%, n=26) of the studies employed a quasi-experimental design. Twenty studies had a follow-up evaluation, after the initial pre-test-post-test evaluation. The time period that elapsed before the follow-up evaluation ranged between 2 weeks and 12 months.

The majority (87%, n=32) of the included studies either adopted surveys only or surveys with other forms of data collection tools. Surveys were used to assess knowledge, attitudes, self-reported practice/behaviours, self-efficacy, confidence, and feedback. Most of the surveys were developed by the authors and they usually did not report their psychometric properties. In all the interventions that assessed change in knowledge, multiple choice questions (ranging between 1 and 78 questions) were used. Changes in attitude before and after the intervention were assessed using Likert statements.

Behavioural changes were measured either as reported practice using questionnaires or through observations during practice after interventions. For example, one educational intervention used incognito standardized patients to assess practice behaviour after an intervention [24]. Another study [25] measured nutrition indices such as wasting, stunting and underweight in children to determine the impact of an educational intervention to improve the quality of nutrition counselling given to mothers/care givers by physicians.

Table 1: Summary of the findings of educational interventions reviewed (n=37)

Ref no.	Authors	Intervention type	Study location	Participants	Study design	Outcomes
ID019	Levy et al., [26]	Workshop	US	Primary health care professionals (physicians, nurses, physician assistants)	Pre-and posttest without control group	• Self-reported improvement in knowledg between pre-and posttest • Self-reported satisfaction with intervention • Increased confidence to counsel patients on breastfeeding practices • More likely to speak to patients on breastfeeding
ID004	Carson (2003) [27]	Part of ambulatory Clerkships	US and 4th year medical students		Cross-sectional	• Increased self-reported knowledge • Probable changes in practice behaviour
ID032	Taren et al (2001)[28]	Taken as required courses	US	Preclinical medical students	Pre-and posttest with control group	• Significant increase in nutrition OSCE scores between pre-and posttest • Increased self-reported satisfaction in nutrition content of the curriculum
ID016	Buckley 2003 [29]	Varied formats (web-based, web-enhanced and traditional lectures)	US	4th year nursing students	Cross-sectional	• No significant changes in knowledge between the three formats • Web-enhanced had the more positive perception than the web-based and traditional
ID028	Ray et al 2012[30]	Lectures, demonstrations, and interactive practical sessions	UK	3rd and 4th clinical students	Pre-and posttest without control group	• Significant improvement in knowledge scores between pre-and posttest • Changes in attitude scores • Students reported satisfaction with the course • Knowledge acquired applied to patients
ID017	Ke et al 2008 [31]	Workshops	Taiwan	Nurses in ICU, GI and GS	Randomised control trial	• Significant improvement in knowledge between pre and posttest

						• Significant changes in mean attitude sco • Significant changes in behavior intention
ID003	Buchowski et al 2002[32]	Computer-based Required course	US	First year Medical students	Pre-and posttest without control group	• Increased in knowledge scores between pre and posttest • Students developed positive attitudes towards nutrition after intervention • Mixed results with regards to confidence to counsel patients on nutrition
ID054	Puoane et al 2006 [33]	Workshops	South Africa	Nurses	Pre-and posttest without control group	• Change in attitudes towards malnourishe children after intervention • Change in perceptions about malnourish children after training • Reduction in case fatalities
ID014	Hillenbrand and Larsen 2002[34]	Workshops	US	Paediatric residents	Pre-and posttest without control group	• Intervention improved the knowledge of paediatric residents about breastfeeding • Participants confidence increased after th intervention • Limited changes in participants practice behavior after intervention
ID021	Maiburg 2003 [24]	Computer-based instruction	The Netherlands	GP trainees	Pre-and posttest with control group	• Improvement in knowledge scores after intervention • Changes in practice behaviour
ID024	Ockene et al [35]	Workshop	US	Internists	Randomized control trial	• No significant changes in self-reported knowledge scores • Limited changes in attitudes • Counselling scores increased between pr and posttest
ID055	Zaman et al 2008[36]	Workshop	Pakistan	Health care workers	Randomized control trial	• Improvement in communication skills • Improvement in consultation performanc Mothers able to recall recommendation c health workers

ID038	Eisenberg et al 2013[37]	Workshop	US	Physicians and other healthcare professionals	Pre-and posttest without control group	• Self-reported significant positive change in ability to counsel obese patients • Changes in participants nutrition behaviours
ID029	Roche et al 2007 [38]	Computer-based instruction	US	Paediatric residents	Randomized control trial	• Limited modest improvement in self-reported knowledge scores after intervention • Positive attitudes towards computer instruction after intervention • Participants believed intervention enhanced their knowledge in nutrition
ID056	Gance-Cleveland 2008 [39]	Workshop	US	Nurse practitioners	Pre-and posttest without control group	• Post training results revealed significant improvement in practitioner knowledge • Post training results revealed significant improvement in practitioners intent to improve behavior • Post training results revealed significant improvements in practitioners report of increased confidence in ability to addres barriers
ID027	Ray et al 2014 [40]	Workshop	UK	Junior doctors	Pre-and posttest without control group	• Significant improvement in knowledge, attitude and practice scores
ID057	Bassichetto and Rea 2008 [41]	Workshop	BRAZIL	Paediatricians and nutritionists	Randomized control trial	• Significant improvement in knowledge scores after intervention • Improvement in dietary counselling afte intervention
ID009	Dacey et al 2013 [42]	Workshop	US	Physicians and other health care professionals	Pre-and posttest without control group	• Improvement in the perception of barrie to lifestyle medicine • Improvement in self-reported knowledge • Increased confidence to counsel

ID033	Tziraki and Graubard 2000 [13]	Workshop	US	Primary care physicians	Randomized controlled trial	• Change in practice behavior • Changes in office environment to be conducive for nutrition screening and dietary advice
ID053	Edwards and Wyles 1999[43]	Workshop	UK	Healthcare professionals	Pre-and posttest without control group	• Improvement in knowledge after training • Participants enjoyed most parts of the training
ID006	Castro et al 2013 [44]	Workshop	Brazil	Physicians in the ICU	Pre-and posttest with control group	• Significant improvement in knowledge after the intervention • Reduction in the length of stay of patient in the ICU
ID050	Pelto et al 2004 [25]	Workshop	Brazil	Doctors	Randomized control trial	• Changes in physician behavior and practice • Mother's uptake of physician advice • Reduction in malnutrition cases
ID018	Kohlmeier et al 2000[45]	Computer-based instruction	US	First year medical students	Pre-posttest without control group	• Significant improvement in knowledge a attitudes after intervention
ID049	Bjerrum 2012 [46]	Workshop	Denmark	Nurses	Pre-and posttest without control group	• Changes in knowledge and attitudes • Level of satisfaction with intervention
ID051	Pedersen et 2012 [47]	Workshop	Denmark	Nurses	Pre-and posttest without control group	• Changes in nutrition practice behavior • Changes in the eating difficulities of patients
ID008	Conroy et al 2004 [48]	Required course	US	2nd year medical students	Pre-and posttest without control group	• Personal dietary, exercise patterns of participants • Confidence in their ability to address die and exercise in patients
ID012	Endevelt,	Workshop	Israel	2nd year medical	Cross-sectional	• Changes in knowledge

	Shahar & Henkin, 2006 [49]			students		
ID011	Olivarius et al 2005 [50]	Seminar	US	Primary care physicians	Pre-and posttest with control group	• Changes in personal dietary behaviors of participants • Changes in attitudes towards dietary counselling
ID030	Schlair et al 2012 [51]	Workshop	US	First year medical students	Pre-and posttest without control group	• Changes in self-efficacy scores • Changes in attitudes • Changes in nutrition counselling competence • Changes in personal dietary habits
ID031	Scolapio et al 2008 [52]	Workshop	US	Physicians, dieticians and pharmacist	Pre and posttest with control group	• Changes in knowledge • Confidence in counselling patients on nutrition • Changes in practice behaviours
ID052	Kennelly et al 2010[53]	Workshop	Ireland	GPs and nurses	Pre-and posttest without control group	• Changes in knowledge • Changes in practice behaviours • Level of acceptance for the intervention
ID040	Lewis et al., 2014 [54]	Internet-based	US	Paediatric trainees	Cross-sectional	• Change in knowledge • Engagement with course content • Level of satisfaction with intervention
ID035	Acuna et al 2008 [55]	Workshop	Brazil	Medical and nursing students	Pre-and posttest without control group	• Ability to diagnose malnutrition
ID025	Powell-Tuck et al 1997 [56]	Required course	US	2nd year medical students	Pre-and posttest without control group	• Students' feedback • Changes in knowledge

ID01	Afaghi et al 2012 [57]	Workshop	Iran	Clinical year 4 and 5	Pre-and posttest without control group	• Student perceptions of the adequacy of t instruction • Changes in knowledge
ID005	Carson et al 2002 [58]	Required course	US	4th year medical students	Pre-posttest with control group	• Changes in knowledge • Change in attitude • Self-efficacy in addressing nutrition issu
ID05	Vanderpool et al., 2014 [59]	CME	US	Paediatric gastroenterology fellows and paediatric gastroenterologists	Pre-and posttest without control group	• Changes in knowledge • Reported changes in behavior • Reported changes in patient outcomes

Intervention focus, types, teaching and learning formats, duration of interventions and expected learning outcomes

Eleven studies (30%) explicitly stated the theoretical underpinning of the intervention including experiential, social, and cognitive learning theories. The rest did not. The educational interventions focused on improving competencies (knowledge, skills and attitudes) of participants in a variety of nutrition topics (as shown in table 1). Studies from developing countries covered topics mainly related to infant and young child feeding practices and those from developed countries covered topics relating to hospital malnutrition and nutritional management of chronic diseases. Studies that had students as participants usually set out to improve curricula and/or increase the number of hours devoted to nutrition education. Those among practitioners were largely continuing medical education (CME) programs to improve knowledge, attitudes and skills and practice behaviour in specific topics such as breastfeeding practices and dietary counselling.

Teaching and learning formats included lectures, PBL tutorials, nutrition slogans, demonstrations, role plays, group discussions, games and video presentations. All studies employed more than one teaching and learning format except in three interventions that were lecture-based only and computer-based only. Innovative teaching and learning methodologies were prevalent in almost all of the interventions. Generally, studies involving students were obligatory of longer duration ranging from 2 weeks to 4 years. Those involving health professionals were shorter. The shortest was a one hour intensive session for general practitioners and other health care professionals on giving folic acid to women of childbearing age [43]. The longest intervention was a required course/curriculum for medical students which had duration of four years. A lack of consistency in reporting the duration of interventions made it difficult to determine mean and median duration. Varied terms including credit hours, number of days, weeks and years were used to describe the length of the interventions.

Table 2: Study designs and data collection methods employed by the included studies

Study design	**Frequency (%)**
Randomised control trials	7(19%)
Quasi-experimental	
Pre-test-post-test with control group	8(22%)
Pre-test-post-test without control group	14(38%)
Cross-sectional	4(11%)
Methodological approach	
Qualitative	4(11%)
Quantitative	24(65%)
Both qualitative and quantitative	9(24%)
Data collection methods employed	
Questionnaires/surveys only	24(65%)
Observations only	2(5%)
Focus group discussions only	2(5%)
Questionnaires/survey with other methods (e.g. interviews, observations)	9(24%)
Topics covered by the interventions	
Dietary assessment, advice and management	11(30%)
Hospital malnutrition	8(22%)
Infant and young child feeding practices including breastfeeding	6(16%)
Nutritional management of chronic diseases	7(19%)
Cancer and nutrition	2(5%)
Intestinal problems	3(8%)
Vitamins, minerals, exercise and lifestyle medicine	2(5%)
Leadership strategies to improve nutrition care in hospitals	1(3%)
Culinary skills	1(3%)
Format of intervention	
Training programs	13(35%)
Workshops	7(19%)
Required courses	5(14%)
Technology-based (computer-based, internet-based)	7(19%)
Ambulatory clinical rotations	1(3%)
Seminars	1(3%)
CMEs	3(8%)
Healthcare practitioners (n=21, 57%)	
Physicians (general practitioners/primary care)	7(19%)
Nurses	6(16%)
Multidisciplinary participants (e.g. nurses, physicians, pharmacists)	8(22%)
Students (n=16, 43%)	
Undergraduate preclinical training	7(19%)
Undergraduate clinical training	5(13.5%)
Postgraduate (Paediatric residents)	4(11%)

Context-Mechanisms-Outcomes Configurations

A shown in table 3 we present here the context-mechanism-outcome configurations emerging from the included studies.

Improving skills development instead of cognitive outcomes

Educational interventions were less likely to result in change in nutrition practice behaviour when they emphasised on only improving cognitive outcomes of the participants. These interventions were triggered from a context of healthcare professionals' reported lack of knowledge as a barrier to the delivery of nutrition care. In four of our included studies, authors reported significant changes in knowledge gains which did not predict practice scores [30]; did not result in students' assessment of the nutrition status of overweight patients ([27]; did not influence behaviour change intentions [31] and did not affect dietary counselling for mothers/caregivers of children aged 12-24 months [41]. Except one [43], all of these interventions were conducted in the settings of undergraduate education [29 32 49 54 56 57]. Two included studies reported non-significant nutrition knowledge gains but significant increases in physician use of dietary counselling steps from audiotaped physician-patient [35 42] and self-reported counselling behaviour and confidence [42]. These interventions emphasised on improving the skills of the participants instead of knowledge and incorporated opportunities for skills building. In the Ockene et al [35] study authors noted that "a large proportion (1.5hr) of the entire 3-hour CME training program was devoted to the learning of counselling and dietary assessment skills". It therefore suffices that focussing on skills development and creating learning environments that encourages the acquisition of skills are critical in changing healthcare professionals' nutrition care behaviour [60 61].

Table 3: Context, mechanism and outcome configuration

Context	Intervention characteristics	Mechanisms triggered	Outcome
Future healthcare professionals Healthcare professionals Lack of time Lack of patient motivation to change dietary pattern Lack of diet counselling training Lack of knowledge	Improving Personal health habits of healthcare professionals	Sense of confidence Sense of being a role model for the patient Sense of relatedness to the patient	Counselling confidence Intentions to change behaviour Self-reported healthy lifestyles Self-reported dietary assessment Increased self-assessed cognitive outcomes Attitudes favourable to nutrition counselling
In the hospital setting Practicing healthcare professionals Future healthcare professionals/students Clinical rotations	Role modelling	Sense of confidence Sense of acceptance Credibility Anticipation of being valued	Enhanced students' confidence Fostered the delivery of nutrition care in the clinical setting
Health care professionals Lack of appropriate tools Personal practices regarding nutrition Inadequate training in nutrition Do not address nutrition problems with patients Structural barriers to nutrition	Providing participants with local, practical relevant tools and messages	Removal of perceived barriers Feels Comfortable	Facilitated the uptake of nutrition messages Change in nutrition practice behaviour Engage in specific rather than general discussion with patients Give relevant advice and recommendations to patients Simplification of traditional complex messages
Lack of confidence to deliver nutrition care Healthcare professionals Future healthcare professionals	Emphasizing on improving self-efficacy	Feels motivated Feels Confident	Self-reported changes in practice behaviours Intentions to change behaviour

Lack of adequate skills Lack of knowledge and skills Healthcare professionals Future healthcare professionals	Skills building	Sense of confidence Feels adequately prepared	Use of dietary counselling steps Self-reported counselling behaviour Self-reported confidence to counsel patients
Lack of time Lack of payments and referral sources and materials Poor investments Lack of supportive office systems to deliver nutrition care Separation of prevention and curative services in the health care system Healthcare professionals	Improving the work environment	Feels comfortable to deliver nutrition care Sense of acceptance Perceives less of barriers to the delivery of nutrition care Sense of Recognition	Acquired strategies to address lack of support systems Significant reduction in perception of health system barriers to lifestyle medicine Structured office environment to be conducive to providing nutrition-related services for cancer prevention
Poor interest for nutrition education	Use of non-traditional teaching and learning strategies	Captures interest of participants Meet the learning needs of participants Active participation and uptake of knowledge and skills Relevancy of learning	Significant changes in knowledge gains Positive personal health habits of participants Ability to counsel overweight/obese patients. Exercise counselling Dietary counselling Management of malnutrition,
Inadequate instruction for nutrition education, Inadequate nutrition content Lack of time to attend continuing education programs in nutrition for busy healthcare	Incorporation of technology-based education	Sense of convenience	Significant gains of knowledge Positive attitudes Self-assessed skills of providing nutrition counselling Improvement in counselling skills Real-time practice behaviour

professionals.			
Low priority given to nutrition Inadequate time dedicated to nutrition Healthcare students Reported inadequate knowledge in nutrition	Integration of nutrition content	Acceptance of nutrition education Reduction in perception of time limitations	Relevance of nutrition education Increased in the number hours dedicated to nutrition Increased cognitive outcomes
Multidisciplinary nature of healthcare delivery Cross-disciplinary nature of nutrition	Adopting a multidisciplinary approach in intervention design and implementation	Team work Belonging Acceptance Recognises the multidisciplinary nature of nutrition healthcare delivery	Multi-disciplinary designed program Meets the needs of all participants Increased satisfaction
Future healthcare professionals Practicing healthcare professionals	Meeting the needs of the participants	Interests Sense of knowing the needs of participants	Increased satisfaction

Superiors encouraging the delivery of nutrition care (Role modelling) ("I look up to you")

As we stated in the candidate theories of our protocol [20], healthcare professionals may deliver nutrition care if they see their superiors' model the same behaviour. When interventions involved participants having the opportunity to see their superiors model nutrition care behaviour, they were more likely to report significant changes in nutrition practice behaviour through mechanisms such as feeling a sense of confidence, acceptance, credibility and anticipation of being valued. Some of the forms in which role modelling was incorporated into the interventions included the use of virtual physician mentor [32], simulation of GP consultation using video clips [24], using expert views from physicians describing how they addressed nutrition in practice and role modelling by physicians in classes [62].

Meeting the needs of potential participants of an intervention ("Ask me what I want")

Needs assessment provides a great opportunity to affect positively the needs of the learner [52]. Recognising this fact most interventions were modelled on the theory that educational interventions will be successful if there are designed according to the needs of the participants. Needs assessment were employed to identify the gaps in knowledge or practice behaviour [52]; identify the educational needs of the participants and methods in which potential participants learnt best. Information obtained from the needs assessments were used to inform the content, format and design of the curriculum. This then resulted in the incorporation of appropriate teaching and learning methodologies promoted the interest of the participants, acceptability, receptivity, satisfaction and placing a high value on the training.

Addressing structural and systemic factors ("Is my consulting room enabling")

From a context of structural and systemic barriers to the delivery of nutrition care, interventions that emphasised on improving the work environment were more likely to influence the nutrition practice behaviour of participants. It was evident that nutrition education alone may not give the desired impact on healthcare professional nutrition care attitude and behaviour, structural and organisational changes are also needed in the healthcare setting to change behaviour and maintain it [47]. As observed in eight of our included studies, addressing structural and systemic barriers resulted in participants acquiring appropriate strategies to address lack of support systems [39] to deliver nutrition care, significantly reducing participants' perception of health system barriers to deliver nutrition care [42] and participants' restructuring their office environment to be conducive to providing nutrition-related services disease prevention [13]. These created a conducive environment for the delivery of nutrition care. In providing explanations for the success of an educational intervention that had direct effects on physician behaviour, Pelto et al [25] stated that "structural conditions in the public health system in Pelotas provided an environment in which physicians could utilize their knowledge". Structural and systemic barriers were addressed by the provision of nutritional messages that could be delivered by busy primary care providers [26], presentation on change management and leadership [40] and provision of guidelines on office organization for the delivery of nutrition care [13]. It emerged that collaboration between education and care delivery leaders is required to help remove structural and systemic barriers.

Incorporation of technology-based education

Complete computer-based and internet-based interventions were designed in response to inadequate instruction for nutrition education, inadequate nutrition content and lack of time to attend continuing education programs in nutrition for busy healthcare professionals. Seven studies were presented in this format. Computer-based and internet-based interventions helped to avoid the major problem of lack of nutrition faculty, allowed easy update and distribution of updates [24], permitted self-directed and independent study of nutrition information [24 38], provided consistent presentation of content [62] and were convenient for participants as they

were self-administered [24 62]. These interventions that were computer-based and internet based reported significant gains of knowledge [32 38 45 54], positive attitudes [24 38] and self-assessed skills of providing nutrition counselling [45]; improvement in counselling skills [24]; and real-time practice behaviour [24]. These outcomes were attained through mechanisms such as sense of convenience, interest and independent learning.

Providing participants with local, practical relevant tools and messages ("Give me tools")

This strategy emanated from a context of healthcare professionals working in the clinical setting who report lack of appropriate tools and messages to deliver nutrition care to patients. Hypothetically, making available to healthcare professionals; local, practically relevant tools and messages during training may result in changes in their nutrition practice behaviour. The included studies incorporated this strategy by providing participants with specific language and appropriate tools for addressing nutritional issues such as the use of memorable slogans [26]; use of simple key take home messages [26 30 33 53]; personalizing nutrition messages [26] and providing local relevant examples [25]; simplification of nutrition messages [26]; resource materials and tools to help in counselling and assessing patients problems [25 53] and adapting advice for local conditions [25]. Through this mechanism healthcare professionals engaged in specific rather than a generic discussion with patients, provided advice or recommendations that are relevant and known to the patient [25] and simplified traditional complex messages [26]. In a randomized controlled trial that improved the physician counselling of mothers with malnourished children aged 12-24 months in Brazil [25], authors attributed the success (i.e. improved nutritional status of children) of the training program to the provision of locally appropriate messages, tools for assessing individual problems, and counselling skills.

Use of non-traditional teaching strategies ("Using the right strategy for the right job")

Some studies were also modelled on the theory that using non-traditional strategies of teaching and learning will result in changing nutrition practice behaviour of healthcare professionals. For example, Hillenbrand et al 2002 [34], hypothesized prior to their intervention on improving the breastfeeding counselling confidence of paediatric trainees, that a series of interactive educational interventions about breastfeeding for paediatric residents would result in an increase in knowledge about breastfeeding and lactation problems and increased confidence when counselling breastfeeding women. Sometimes incorporating them with traditional-lecture based formats, the included studies incorporated non-traditional teaching and learning strategies such as interactive lessons/discussions, simulated patient cases, use of visual physician mentor, group work, role plays, hands-on demonstrations, group practice, panel discussions and case-based learning.

Furthermore non-traditional teaching and learning strategies incorporated by the included studies were problem-based learning tutorials, computer-based/web-based cases, student-led debates, self-assessment exercises and clinical case presentations. Incorporation of these strategies provided practical experience, active participation, emphasised on the development of skills instead of knowledge acquisition and allowed participants to assume responsibility of their learning and engaging the interest of participants. Even though authors did not indicate which teaching and learning strategy resulted in which outcome, most of the interventions that incorporated these strategies reported significant changes in knowledge gains, personal health habits of participants, ability to counsel overweight/obese patients, exercise counselling, dietary counselling, and the management of malnutrition. In their intervention that reported significant changes in self-efficacy for providing nutrition counselling after following a four week ambulatory care rotation in nutrition, Carson et al 2002 [62] indicated that the "inclusion of computer-based cases, pocket references, and class discussion on cardiovascular nutrition resulted in significant gains in knowledge and self-efficacy for the experimental students than for the control students."

Improving self-efficacy ("I feel that I can do it, so I will do it")

Self-efficacy is a basic tenet of Bandura's social learning theory. According to Bandura [63] self-efficacy—one's confidence in his/her ability to perform a task or to achieve an outcome—is a key influence on behaviour. Eight of our included studies placed emphasis on improving self-efficacy of participants to deliver nutrition care. From a context of reported lack of confidence to deliver nutrition care, these interventions hypothesised that improving the confidence level or the self-efficacy of healthcare professionals will result in the delivery of nutrition care. In order to improve the self-efficacy of participants these interventions implemented teaching and learning strategies such as role modelling by practicing physicians [62]; role playing using either simulated or real patients [34 35 39 48], demonstrations and hands on practice sessions [26 34 35 37 39 51 62], viewing and discussion of videos and web-based cases [35 58]. Four each were conducted among future healthcare professionals and in health care professional. In both settings the interventions were effective in changing the nutrition care behaviour of participants. It is pertinent to note that the changes in nutrition care behaviours reported by authors were self-reported changes in practice behaviours [26 35 37 42 48] or intentions to change behaviour [39] in all, except in two [34 58].

Improving the personal health habits of the healthcare professional ("Do as I do")

In the context of both practicing and future healthcare professionals, when interventions involved the promotion of personal healthful habits of the participants, they reported positive outcomes. Two interventions each in the context of healthcare professionals [37 50] and in future healthcare professionals[48 51] followed this mechanism. These interventions promoted healthful lifestyles such as regular consumption of fruits and vegetables; personal awareness of calorie consumption; engaging in regular physical activity and culinary skills. In both settings, these interventions resulted in positive changes in self-reported healthy lifestyles and self-reported dietary assessment ability [51], counselling confidence [37 48 51], increased self-assessed knowledge [50], and reported proportion of diabetic patients treated with diet [50]. Through this mechanism the healthcare professionals considered themselves to be models for the patients and in order to be able to advice patients they themselves should follow a healthful lifestyle.

Revised programme theory

Taking cognisance of the evidence of this review we present a revised programme theory (shown in figure 2) quite different from our initial programme theory published in the protocol [20]. The items in this model do not operate in isolation, they are interrelated and inter-linked. It is theorized that needs assessments are carried out to identify knowledge, skills and attitude gaps of potential participants. The outcome of the needs assessment process informs the design of the educational intervention as well as its characteristics. It informs what kind of strategies (characteristic of the intervention) that should be adopted in order to realise the desired outcome. These strategies (characteristics of the intervention) could include improving personal health habits of healthcare professionals, adoption of technology-based education, improving skills development, adopting innovative teaching and learning strategies, role modelling, and among others. These will generate mechanisms (not indicated in the diagram) to generate outcomes such as improved knowledge, attitude, skills, self-efficacy, values and personal habits. But then these may only be translated into change in nutrition practice behaviour if there is an enabling environment to demonstrate such behaviour. The healthcare professionals' nutrition practice behaviour is enhanced by certain conditions such as restructuring of the healthcare system, favourable policies for nutrition care, provision of appropriate tools to deliver nutrition care, improving investments in preventive care, providing a conducive and an enabling office for nutrition care. A change in nutrition practice behaviour will mean increased delivery of nutrition care to patients which will result in the ultimate goal of improved clinical outcomes of patients.

=Insert figure 2

We present in table 4 characteristics of the interventions in accordance with what works, for whom, under what conditions.

Table 4: What works, for whom, under what circumstances, to achieve what?

What works	Identifying educational and clinical relevant interventions based on the needs of the participants Adopting appropriate teaching and learning techniques Building on self-efficacy and confidence through role modelling Emphasizing on skills development instead of cognitive outcomes Improving the personal lifestyle habits of healthcare professionals Removing systemic barriers and restructuring the healthcare system Use practical relevant tools The use of ICT (computer-based education)
For whom	Doctors and other practicing healthcare professionals Health professions students
Under what circumstances	Requires a multidisciplinary approach Support from both educational and care delivery leaders Recognition of nutrition care as a component of the care delivery system Recognizing nutrition as an important component of the medical curriculum Structuring of the healthcare system to be conducive for the practice of nutrition care
To achieve what outcomes	Achievement of both educational and clinical outcomes Sustainability of educational outcomes for the clinical setting

Measurement issues

Based on Miller's pyramid of assessment, only seven studies employed methods that assessed the performance level i.e. the delivery of nutrition care in clinical setting through direct observations [13 25 34 36 41], recorded videos of doctors counselling patients [13], chart audits[33 55 62] and incognito simulated patients[24]. The rest employed surveys which were self-administered to assess participants' reported change in practice behaviours. As observed by the authors of one of such studies [48]; reliance on students' self-reported confidence in counselling rather than an objective measure of counselling skills, such as an objective structured clinical examination limits the generalizability of the findings. In describing one of the limitations of their study Schlair et al [51] noted that the potential for social desirability bias in using self-reports.

The ultimate aim of an educational intervention to improve the delivery of nutrition care is to result in improved clinical and patient outcomes. However, few studies addressed this issue. Authors noted difficulty in measuring these outcomes as a limitation [52]. Authors were therefore speculative on the influence of the interventions on clinical and patient outcomes. For future studies Scholapio et al [52] suggested that this data could be obtained using methods such as patient surveys, chart reviews, or having participants give specific examples of improved patient outcome that can be directly linked to the knowledge they had acquired from the educational intervention. Notwithstanding the significant benefits of such information, future studies should explore innovative ways of collecting this information [52].

Discussion

The CMOCs identified in this realist review are preliminary and non-exhaustive and should be considered as a set of generic hypotheses derived from the evidence available. Nonetheless, they provide valuable information to policy makers on what may work for whom, how and under what conditions or settings to help improve the nutrition practice behaviour of doctors and other healthcare professionals. It brings to light conditions that facilitate the success of interventions to improve the delivery of nutrition care in varied contexts.

Our analysis supports planners of educational interventions to collect relevant data from potential participants through needs assessment to address participants' needs and interest. Computer and internet based education presents an opportunity for course designers and planners. Already considered as a potentially efficient form of teaching and learning in the health professions [38 64-66] computer- and internet-based education presents a novel opportunity to incorporate nutrition content into the curricula of future health professionals. Given the context of reported lack of time by healthcare professionals to attend training programs and to provide nutrition care, computer-and internet-based education is a great opportunity to overcome this barrier due to its potential to offer convenience to learners.

As evidenced by this review, improving skills, self-efficacy and attitudes of learners by adopting appropriate teaching and learning strategies is very critical to the success of nutrition education interventions to change practice behaviour in the settings of both practicing and future healthcare professionals. Improving learners' skills and attitudes will provide participants a sense of confidence and enactive mastery of the specific task/skill.

In the settings of healthcare professionals, role modelling of the delivery of nutrition care by superiors, providing conducive office for the delivery of nutrition care and the presence of favourable policies in the healthcare settings can improve the nutrition practice behaviour of doctors and other healthcare professionals through mechanisms such as: sense of acceptance, credibility, relatedness and assurance.

It is imperative to note that individual experts in this field were not consulted. Had this been done we might have had more candidate theories than presented here. We also acknowledge the interpretive and subjective nature of qualitative research such as these. As such a different team of researchers may arrive at different candidate program theories. The resulting synthesis of any review is as good as the included primary studies; notwithstanding the kind of review method is adopted. Many of the included primary studies provided a limited, superficial description of their educational interventions. This made it difficult for us to fully test all components of our candidate theories and to provide richer descriptions of some of the mechanisms that were identified.

Corroborating other reviews in medical education [21 67 68] this review was limited by the lack of descriptions of the context of the intervention, implementation processes and mechanisms by authors of most of the included studies.

Acknowledgement

The authors wish to thank Mr. Fuseini Abdulai Braimah, senior library assistant, School of Medicine and Health Sciences, University for Development Studies for his support in helping to retrieve full texts of some included studies.

Funding

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

Competing interest

None

Contributors: VM and TM were responsible for the conception and design of the study. VM was principally responsible for searching, sourcing and initial screening of studies. VM, MGC and TM further screened studies based on abstracts. Quality assessment was done by VM, AS, FS and MGC. VM was responsible for data extraction, synthesis and interpretation of the data and drafting of the manuscript. AS, TM, FS, MGC and PA contributed to interpretation of the data and revision of the article. All authors approved the article for publication.

Provenance and peer review: Not commissioned; externally peer reviewed.

Data sharing statement: VM had full access to all the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

References

1. Pearson TA, Blair SN, Daniels SR, et al. AHA guidelines for primary prevention of cardiovascular disease and stroke: 2002 update consensus panel guide to comprehensive risk reduction for adult patients without coronary or other atherosclerotic vascular diseases. Circulation 2002;**106**(3):388-91
2. Bantle JP, Wylie-Rosett J, Albright AL, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2008;**31**:S61-S78
3. Goldstein LB, Adams R, Alberts MJ, et al. Primary Prevention of Ischemic Stroke A Guideline From the American Heart Association/American Stroke Association Stroke Council: Cosponsored by the Atherosclerotic Peripheral Vascular Disease Interdisciplinary Working Group; Cardiovascular Nursing Council; Clinical Cardiology Council; Nutrition, Physical Activity, and Metabolism Council; and the Quality of Care and Outcomes Research Interdisciplinary Working Group: The American Academy of Neurology affirms the value of this guideline. Stroke 2006;**37**(6):1583-633
4. United Nations Children's Fund. Improving Child Nutrition:The achievable imperative for global progress. In: Fund UNCs, ed. New York, 2013:1-124.
5. Kopelman P, Lennard-Jones J. Nutrition and patients: a doctor's responsibility. Clinical Medicine 2002;**2**(5):391-94
6. Council GM. Tomorrow's doctors: Outcomes and standards for undergraduate medical education. Manchester, UK: General Medical Council 2009
7. Abid A, Galuska D, Khan L, Gillespie C, Ford E, Serdula M. Are healthcare professionals advising obese patients to lose weight? A trend analysis. MedGenMed: Medscape general medicine 2004;**7**(4):10-10
8. Tsai AG, Wadden TA. Treatment of obesity in primary care practice in the United States: a systematic review. Journal of general internal medicine 2009;**24**(9):1073-79
9. Huang J, Yu H, Marin E, Brock S, Carden D, Davis T. Physicians' weight loss counseling in two public hospital primary care clinics. Academic Medicine 2004;**79**(2):156-61
10. Laschinger HKS, Tresolini CP. An exploratory study of nursing and medical students health promotion counselling self-efficacy. Nurse Education Today 1999;**19**(5):408-18 doi: 10.1054/nedt.1999.0326[published Online First: Epub Date]|.
11. Jay M, Gillespie C, Ark T, et al. Do internists, pediatricians, and psychiatrists feel competent in obesity care? Journal of general internal medicine 2008;**23**(7):1066-70
12. Foster GD, Wadden TA, Makris AP, et al. Primary care physicians' attitudes about obesity and its treatment. Obesity Research 2003;**11**(10):1168-77

13. Tziraki C, Graubard BI, Manley M, Kosary C, Moler JE, Edwards BK. Effect of Training on Adoption of Cancer Prevention Nutrition-Related Activities by Primary Care Practices: Results of a Randomized, Controlled Study. Journal of general internal medicine 2000;**15**(3):155-62
14. McLaren DS. Nutrition in medical schools: a case of mistaken identity. Am J Clin Nutr 1994;**59**(5):960-3
15. Weinsier RL. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1995: medical-nutrition education--factors important for developing a successful program. Am J Clin Nutr 1995;**62**(4):837-40
16. Gershoff SN. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1996: nutrition education--success or failure? Am J Clin Nutr 1996;**64**(5):809-12
17. Ball EL, Hughes MR, Leveritt DM. Nutrition in general practice: role and workforce preparation expectations of medical educators. Australian Journal of Primary Health 2010;**16**(4):304-10
18. Mechanic D. Social research in health and the American sociopolitical context: the changing fortunes of medical sociology. Soc Sci Med 1993;**36**(2):95-102
19. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Nutrition training improves health workers' nutrition knowledge and competence to manage child undernutrition: a systematic review. Frontiers in Public Health 2013;**1**
20. Mogre V, Scherpbier A, Dornan T, Stevens F, Aryee PA, Cherry MG. A realist review of educational interventions to improve the delivery of nutrition care by doctors and future doctors. Systematic reviews 2014;**3**(1):148
21. Wong G, Greenhalgh T, Pawson R. Internet-based medical education: a realist review of what works, for whom and in what circumstances. BMC medical education 2010;**10**(1):12
22. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist synthesis: An introduction: ESRC Research methods programme, University of Manchester. RMP Methods Paper 2004;**2**
23. Westhorp G, Walker B, Rogers P, Overbeeke N, Ball D, Brice G. Enhancing community accountability, empowerment and education outcomes in low and middle-income countries: A realist review. 2014
24. Maiburg BHJ, Rethans JE, Schuwirth LWT, Mathus-Vliegen LMH, van Ree JW. Controlled trial of effect of computer-based nutrition course on knowledge and practice of general practitioner trainees. American Journal of Clinical Nutrition 2003;**77**(4S):1019S-24
25. Pelto GH, Santos I, Gonçalves H, Victora C, Martines J, Habicht J-P. Nutrition counseling training changes physician behavior and improves caregiver knowledge acquisition. The Journal of nutrition 2004;**134**(2):357-62
26. Levy J, Harris J, Darby P, Sacks R, Dumanovsky T, Silver L. The primary care nutrition training program: An approach to communication on behavior change. Health Promotion Practice 2011;**12**(5):761-68
27. Carson JAS. Pocket tape measure for waist circumference: Training medical students and residents on a simple assessment of body composition. Journal of Nutrition 2003;**133**(2):547S-49S
28. Taren DL, Thomson CA, Koff NA, et al. Effect of an integrated nutrition curriculum on medical education, student clinical performance, and student perception of medical-nutrition training. American Journal of Clinical Nutrition 2001;**73**(6):1107-12
29. Buckley KM. Evaluation of classroom-based, Web-enhanced, and Web-based distance learning nutrition courses for undergraduate nursing. Journal of Nursing Education 2003;**42**(8):367-70
30. Ray S, Udumyan R, Rajput-Ray M, et al. Evaluation of a novel nutrition education intervention for medical students from across England. BMJ Open 2012;**2**(1) doi: e000417

10.1136/bmjopen-2011-000417[published Online First: Epub Date]|.

31. Ke L-S, Chiu T-Y, Hu W-Y, Lo S-S. Effects of educational intervention on nurses' knowledge, attitudes, and behavioral intentions toward supplying artificial nutrition and hydration to terminal cancer patients. Supportive care in cancer 2008;**16**(11):1265-72
32. Buchowski MS, Plaisted C, Fort J, Zeisel SH. Computer-assisted teaching of nutritional anemias and diabetes to first-year medical students. American Journal of Clinical Nutrition 2002;**75**(1):154-61
33. Puoane T, Sanders D, Ashworth A, Ngumbela M. Training nurses to save lives of malnourished children. Curationis 2006;**29**(1):73-78
34. Hillenbrand KM, Larsen PG. Effect of an educational intervention about breastfeeding on the knowledge, confidence, and behaviors of pediatric resident physicians. Pediatrics 2002;**110**(5) doi: e59

10.1542/peds.110.5.e59[published Online First: Epub Date]|.
35. Ockene JK, Ockene IS, Quirk ME, et al. Physician training for patient-centered nutrition counseling in a lipid intervention trial. Preventive Medicine: An International Journal Devoted to Practice and Theory 1995;**24**(6):563-70
36. Zaman S, Ashraf RN, Martines J. Training in complementary feeding counselling of healthcare workers and its influence on maternal behaviours and child growth: a cluster-randomized controlled trial in Lahore, Pakistan. Journal of health, population, and nutrition 2008;**26**(2):210
37. Eisenberg DM, Miller AM, McManus K, Burgess J, Bernstein AM. Enhancing medical education to address obesity:"See one. Taste one. Cook one. Teach one.". JAMA Internal Medicine 2013;**173**(6):470-72
38. Roche PL, Ciccarelli MR, Gupta SK, Hayes BM, Molleston JP. Multi-School Collaboration to Develop and Test Nutrition Computer Modules for Pediatric Residents. Journal of the American Dietetic Association 2007;**107**(9):1586-89 doi: http://dx.doi.org/10.1016/j.jada.2007.06.008[published Online First: Epub Date]|.
39. Gance-Cleveland B, Sidora-Arcoleo K, Keesing H, Gottesman MM, Brady M. Changes in nurse practitioners' knowledge and behaviors following brief training on the healthy eating and activity together (HEAT) guidelines. Journal of Pediatric Health Care 2009;**23**(4):222-30
40. Ray S, Laur C, Douglas P, et al. Nutrition education and leadership for improved clinical outcomes: training and supporting junior doctors to run 'Nutrition Awareness Weeks' in three NHS hospitals across England. BMC medical education 2014;**14**(1):109
41. Bassichetto KC, Réa MF. Infant and young child feeding counseling: an intervention study. Jornal de pediatria 2008;**84**(1):75-82
42. Dacey M, Arnstein F, Kennedy MA, Wolfe J, Phillips EM. The impact of lifestyle medicine continuing education on provider knowledge, attitudes, and counseling behaviors. Medical teacher 2013;**35**(5):e1149-e56
43. Edwards L, Wyles D. The folic acid message–can training make a difference? Journal of Human Nutrition and Dietetics 1999;**12**(4):317-26
44. Castro MG, Pompilio CE, Horie LM, Verotti CCG, Waitzberg DL. Education program on medical nutrition and length of stay of critically ill patients. Clinical Nutrition 2013;**32**(6):1061-66 doi: http://dx.doi.org/10.1016/j.clnu.2012.11.023[published Online First: Epub Date]|.
45. Kohlmeier M, Althouse L, Stritter F, Zeisel SH. Introducing cancer nutrition to medical students: effectiveness of computer-based instruction. American Journal of Clinical Nutrition 2000;**71**(4):873-77
46. Bjerrum M, Tewes M, Pedersen P. Nurses' self-reported knowledge about and attitude to nutrition–before and after a training programme. Scandinavian Journal of Caring Sciences 2012;**26**(1):81-89

47. Pedersen PU, Tewes M, Bjerrum M. Implementing nutritional guidelines–the effect of systematic training for nurse nutrition practitioners. Scandinavian Journal of Caring Sciences 2012;**26**(1):178-85
48. Conroy MB, Delichatsios HK, Hafler JP, Rigotti NA. Impact of a preventive medicine and nutrition curriculum for medical students. American Journal of Preventive Medicine 2004;**27**(1):77-80 doi: http://dx.doi.org/10.1016/j.amepre.2004.03.009[published Online First: Epub Date]|.
49. Endevelt R, Shahar DR, Henkin Y. Development and implementation of a nutrition education program for medical students: A new challenge. Education for Health: Change in Learning & Practice 2006;**19**(3):321-30
50. de Fine Olivarius N, Palmvig B, Andreasen AH, Thorgersen JT, Hundrup C. An educational model for improving diet counselling in primary care A case study of the creative use of doctors' own diet, their attitudes to it and to nutritional counselling of their patients with diabetes. Patient Education and Counseling 2005;**58**(2):199-202
51. Schlair S, Hanley K, Gillespie C, et al. How medical students' behaviors and attitudes affect the impact of a brief curriculum on nutrition counseling. Journal of Nutrition Education and Behavior 2012;**44**(6):653-57
52. Scolapio JS, Dibaise JK, Schwenk WF, 2nd, Macke ME, Burdette R. Advances and controversies in clinical nutrition: the education outcome of a live continuing medical education course. Nutrition in Clinical Practice 2008;**23**(1):90-95
53. Kennelly S, Kennedy N, Rughoobur G, Slattery CG, Sugrue S. An evaluation of a community dietetics intervention on the management of malnutrition for healthcare professionals. Journal of Human Nutrition and Dietetics 2010;**23**(6):567-74
54. Lewis KO, Frank GR, Nagel R, et al. Pediatric trainees' engagement in the online nutrition curriculum: preliminary results. BMC medical education 2014;**14**(1):190
55. Acuna K, Pires C, Santos G, et al. Detection of nosocomial malnutrition is improved in Amazon region by a standard clinical nutrition education program. Nutricion Hospitalaria 2008;**23**(1):60-67
56. Powell-Tuck J, Summerbell C, Holsgrove G, Garrow J. Four years' experience of an undergraduate medical nutrition course. Journal of the Royal Society of Medicine 1997;**90**(2):67-72
57. Afaghi A, Mohamadi AAHA, Ziaee A, Sarchami R. Effect of an Integrated Case-based Nutrition Curriculum on Medical Education at Qazvin University of Medical Sciences, Iran. . Global journal of health science 2012;**4**(1):112
58. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition education. American Journal of Preventive Medicine 2002;**23**(4):296-302
59. Vanderpool C, Lin HC, Scheimann A. NASPGHAN Nutrition University as a Model for Continuing Education Within Pediatric Nutrition. Journal of Pediatric Gastroenterology and Nutrition 2014;**58**(4):469-71
60. Ockene JK, Kristeller J, Goldberg R, et al. Increasing the efficacy of physician-delivered smoking interventions. Journal of general internal medicine 1991;**6**(1):1-8
61. Bandura A, McClelland DC. Social learning theory. 1977
62. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition eduction. American Journal of Preventive Medicine 2002;**23**(4):296-302 doi: http://dx.doi.org/10.1016/S0749-3797(02)00518-4[published Online First: Epub Date]|.
63. Bandura A. *Self-efficacy: The exercise of control*: Macmillan, 1997.
64. Devitt P, Palmer E. Computer-aided learning: an overvalued educational resource? Medical education 1999;**33**(2):136-39

65. Carr MM, Reznick RK, Brown DH. Comparison of computer-assisted instruction and seminar instruction to acquire psychomotor and cognitive knowledge of epistaxis management. Otolaryngology--Head and Neck Surgery 1999;**121**(4):430-34
66. D'Alessandro DM, Kreiter CD, Erkonen WE, Winter RJ, Knapp HR. Longitudinal follow-up comparison of educational interventions: multimedia textbook, traditional lecture, and printed textbook. Academic radiology 1997;**4**(11):719-23
67. Yardley S, Cottrell E, Rees E, Protheroe J. Modelling successful primary care for multimorbidity: a realist synthesis of successes and failures in concurrent learning and healthcare delivery. BMC Family Practice 2015;**16**(1):23
68. Jones AC, Shipman SA, Ogrinc G. Key characteristics of successful quality improvement curricula in physician education: a realist review. BMJ quality & safety 2015;**24**(1):77-88

PRISMA 2009 Checklist

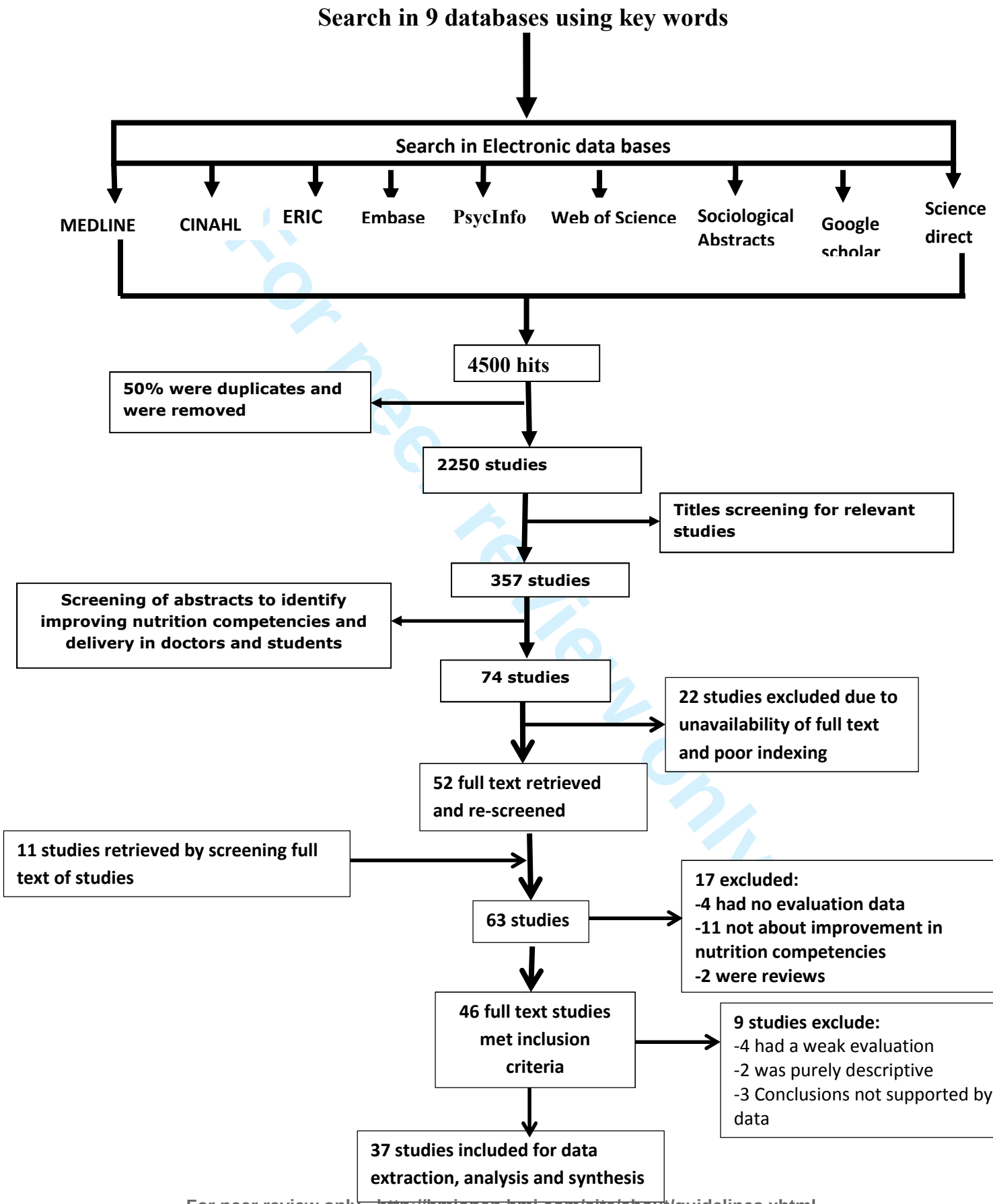
Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2, 5
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5, 6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6, 7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6, 7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Na
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	7

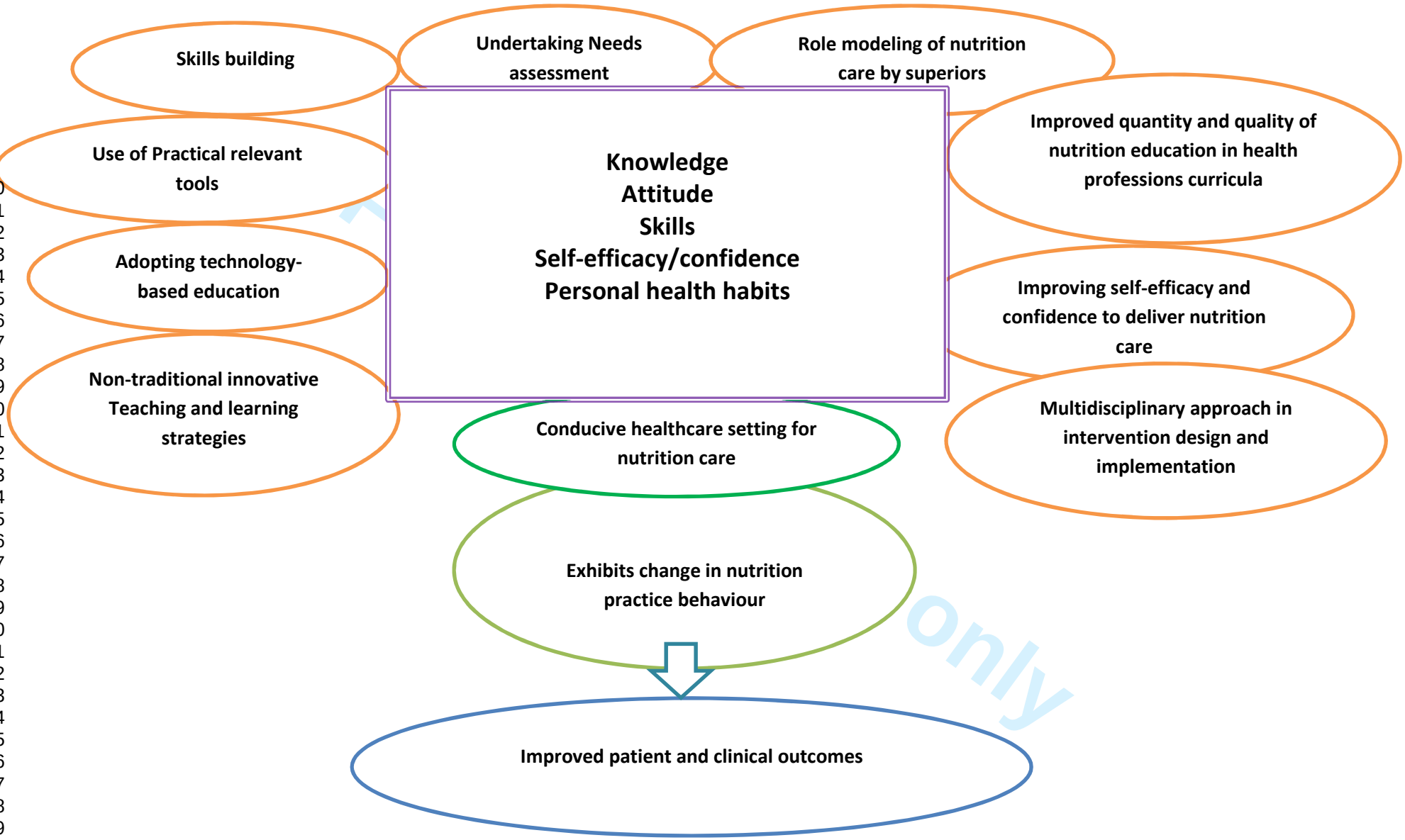
PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Na
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	Na
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8-14
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Na
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Na
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Na
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Na
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Na
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	21
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Na

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.





BMJ Open

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2015-010084.R1
Article Type:	Research
Date Submitted by the Author:	09-Mar-2016
Complete List of Authors:	Mogre, Victor; UNIVERSITY FOR DEVELOPMENT STUDIES, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences Scherpbier, Albert; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Stevens, Fred; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Aryee, Paul ; University for Development Studies,, Department of Community Nutrition, School of Allied Health Sciences Cherry, Mary; University of Liverpool, Department of Health Services Research, Institute of Psychology, Health and Society Dornan, Timothy; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism, Patient-centred medicine, Public health, Qualitative research, Research methods
Keywords:	EDUCATION & TRAINING (see Medical Education & Training), Public health < INFECTIOUS DISEASES, Nutrition < TROPICAL MEDICINE, Realist review; nutrition; educational interventions; doctors; healthcare professionals

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Victor Mogre*[1, 2], Albert J.J.A Scherpbier[2], Fred Stevens[2], Paul Aryee[3], Mary Gemma Cherry[4], & Tim Dornan[2]

[1]Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, School of Medicine and Health Sciences, University for Development Studies, Ghana

[2]School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[3]Department of Community Nutrition, School of Allied Health Sciences, University for Development Studies, Ghana

[4]Department of Health Services Research, Institute of Psychology, Health and Society, University of Liverpool, United Kingdom

*__Corresponding author:__ Victor Mogre, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, University for Development Studies, P. O. Box TL 1883, Tamale.
Email: vmogre@uds.edu.gh

Key words: Realist review; nutrition; educational interventions; doctors; healthcare professionals

Word count: 5256, four tables, and two figures

ABSTRACT

Objective: Determine what types of educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals work, how, for whom, why, and in what circumstances.

Design: Realist synthesis following a published protocol and reported following Realist and Meta-narrative Evidence Synthesis: Evolving Standards (RAMESES) guidelines. A multidisciplinary team searched Medline, CINAHL, ERIC, EMBASE, PsyINFO, Sociological Abstracts, Web of Science, Google Scholar, and Science Direct. The team identified studies with varied designs; appraised their ability to answer the review question; identified relationships between contexts, mechanisms, and outcomes (CMOs); and entered them into a spreadsheet configured for the purpose. The final synthesis identified commonalities across CMO configurations.

Results: Over half of the 46 studies from which we extracted data originated from the US. Interventions that improved the delivery of nutrition care improved skills and attitudes rather than just knowledge; provided opportunities for superiors to model nutrition care; removed barriers to nutrition care in health systems; provided participants with local, practically relevant tools and messages; and incorporated non-traditional, innovative teaching strategies. Operating in contexts where student and qualified healthcare professionals provided nutrition care in both developed and developing countries, these interventions yielded health outcomes by triggering a range of mechanisms, which included: feeling competent; feeling confident and comfortable; having greater self-efficacy; being less inhibited by barriers in healthcare systems; and feeling that nutrition care was accepted and recognised.

Conclusion: These findings show how important it is to move education for nutrition care beyond the simple acquisition of knowledge. They show how educational interventions embedded within systems of healthcare can improve patients' health by helping health students and professionals appreciate the importance of delivering nutrition care and feel competent to deliver it.

STRENGTHS AND LIMITATIONS OF THIS STUDY

1. Application of the principles of realist synthesis to nutrition and education research is novel.
2. The characteristics and conditions of educational interventions that can improve the delivery of nutrition care, identified by this review, are important to the work of policy makers, researchers, health professions educators, and course developers.
3. We found few reports of failed educational interventions, so our findings may have been affected by positive publication bias, as is typical of secondary research.
4. Until our conceptual model is tested and refined in the real world, we consider it to be an indefinite candidate theory, presenting elements worth considering by those concerned with the design, implementation and evaluation of educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals.
5. We cannot assume that the research evidence we identified represents 'real world' practices so our claims for the transferability of this research must be guarded.

PROTOCOL

Published at http://www.systematicreviewsjournal.com/content/pdf/2046-4053-3-148.pdf

INTRODUCTION

Nutrition is an important component of healthcare. It plays a critical role in the prevention and treatment of most cardiovascular and cerebrovascular diseases, which are leading causes of morbidity and mortality throughout the world [1-3]. Nutrition is even more important in sub-Saharan Africa because malnutrition is a major cause of morbidity and mortality, particularly among children [4].

Several landmark reports [5 6] have identified the delivery of nutrition care as one of the core responsibilities of doctors. Research has also shown that nutrition counselling delivered by them has positive influence on patients' clinical outcomes. They and other healthcare professionals whose primary role is not nutrition care, however, often miss opportunities to advise patients on diet and health [7 8]. Health workers in primary care settings are particularly important providers of nutrition care because they can motivate even healthy individuals to adopt healthier lifestyles [9]. The care expected from primary care health workers includes nutrition assessment, education and counselling interventions, monitoring, and evaluation. Lack of knowledge [10], skills, and confidence [11 12] as well as negative attitudes towards delivery of nutrition care and low outcome expectancy [13], are barriers to healthcare professionals providing nutrition care. In addition to these individual-related factors, several system-related factors such as lack of time, office space, payment, materials, and education [14] also prevent the delivery of nutrition care by these healthcare professionals.

Many educational interventions have been designed and implemented to improve nutrition care but their effects have been inconsistent and often weak [15-17]. There remains a need, therefore, for interventions that can change healthcare professionals' behaviour in practice [15-17]. It is imperative to identifty contextual factors, which mediate or inhibit their competence and delivery of nutrition care [18 19]. In order to meet those needs, researchers have to identify components of effective educational interventions and processes.

To date, only one secondary research investigation has synthesised conclusions from existing evidence about nutrition care [20]. The authors of that review concluded that in-service nutrition training improved healthcare professionals' knowledge, nutrition-related counselling skills, and malnutrition management skills. The main limitations were that this was a traditional systematic review, which only considered in-service nutrition training programs. Its authors found that the evidence-base was very heterogeneous; studies had widely varying study designs with heterogeneous outcome measures, and there were wide differences in the competence, experience, and backgrounds of participating healthcare professionals. As the authors acknowledged, systematic review methodology limited their ability to recognize and account for the complexity of interactions within such interventions.

We reasoned that we could move the field forward by conceptualizing nutrition education interventions as complex ones within a realist research approach. As noted in our published review protocol [21], we recognised that educational interventions involve multiple actors operating at different levels with a range of artefacts in varied material environments [22]. We assumed that these components operate in non-linear ways to yield context-dependent outcomes. Realist synthesis explores 'what is it about this intervention that works, for whom and in what circumstances?' and is therefore an appropriate way to study complex interventions [23]. It is an iterative, theory-driven approach, which aims to unpack the theories that inform decisions and actions adopted in the design and implementation of interventions [24]. Realist synthesis begins with the development of an initial programme (or candidate) theory about how interventions, work, the contexts in which they do and do not work, and the differentiated patterns of outcomes that they generate [25]. As the review progresses, researchers test the initial programme theory and refine it as more evidence becomes available [26].

Thus, the aim of this realist review was to determine what types of educational interventions work, how, for whom, why, and in what circumstances to improve doctors' and other healthcare professionals' competencies and delivery of nutrition care.

METHODS

VM is a nutritionist working in sub-Saharan Africa, which provided a context for the research. Other members of the team included scholars of medical education, evidence synthesis, social science, nutrition, and an experienced clinician.

Alteration from protocol

The review question above is broader than in the published protocol [21] because the search showed important findings from research in health professions other than medicine, which the team felt could make a valuable contribution.

Search methods

VM developed a set of search terms based on a combination of synonyms for nutrition, care, healthcare professionals, training etc;scoped the search on two electronic databases; reviewed the articles identified by the search,;concluded there was no need to refine the search terms, and proceeded to the main search. Further explanation and a full list of the search terms can be found in our published protocol [21]; search strategies for individual databases are available from the first author upon request. Using the identified search terms, VM undertook a search of nine data bases including Medline, CINAHL, ERIC, EMBASE, PsycINFO, Sociological Abstracts, Web of Science, Google Scholar, and Science Direct. He joined terms using the Boolean operators 'OR' and 'AND'. In order to cater for different uses of terms, he employed truncation.

Inclusion criteria

- **Study participants:** Medical students, students of other health professions, and practising healthcare professionals (e.g. nurses, physician assistant, etc).
- **Focus of intervention:** Developing participants' competencies in any aspect of nutrition practice behaviour.
- **Study design:** All.
- **Context of intervention:** Medical schools, residency and fellowship programmes, and interventions at both community and hospital settings
- **Language:** Only papers written in English.
- **Publication date:** January 1994 to June 2014 inclusive. This date range was chosen because preliminary searches indicated that educational interventions to improve nutrition care competencies and delivery among doctors and other healthcare professionals gained prominence within published literature around 1994.

Exclusion criteria

We sought to understanding generalists' delivery of nutrition education, therefore we excluded research that only considered the education of dietitians and/or nutritionists since nutrition is their only responsibility. Whilst we excluded conference proceedings, opinion pieces, case studies, and abstracts, we used them to develop the initial candidate theories reported in our protocol [21]. We also excluded systematic reviews, although they informed the design of our data extraction form and provided additional references. Other reasons for exclusion were lack of evaluation or outcome data and studies not being about improvement in nutrition care competencies.

Study selection

Figure 1 shows the flow chart of the search and selection processes. We updated the search immediately before data analysis because there had been a lapse of 6 months between the initial search and that time. We set email alerts from journals and RSS feeds from databases to ensure that we identified new papers as soon as they became available. The final search yielded 4500 hits. VM and TD initially screened the titles of 100 hits independently and compared their findings. There was almost complete agreement as to which articles should be included so VM continued screening alone and, after eliminating duplicates, selected 357 studies. Having obtained their abstracts, VM, TD, and MGC determined independently whether each study was concerned with improving nutrition care competencies and delivery of nutrition care. At a face-to-face discussion, we compared our choices, for which the kappa statistic of agreement was 0.9. This yielded 74 studies, six of which were excluded because they were conference abstracts and seven of which could not be obtained despite repeated attempts. We downloaded the remaining 61 studies into Mendeley reference manager. VM read the reference lists of them all and all systematic reviews he had found, from which he identified 11 more studies, which brought the total to 72 studies.

=Insert figure 1=

Quality assessment

It is regarded as acceptable in realist synthesis to include part(s) or whole studies for analysis and synthesis, provided the methods employed for collecting such data are robust [27]. VM selected 55 of the 72 studies for further consideration based on the inclusion and exclusion criteria, seeking advice from other members of the team whenever he was in doubt. AS, TD, FS and MGC worked with VM to evaluate the 55 studies, excluding nine of them on the grounds of their poor quality and leaving 46 studies for data extraction and analysis. Reviewers' judgements of studies' trustworthiness were based on the appropriateness of their designs, sample sizes, and data collection tools vis-à-vis the outcomes reported. Relevance to our program theory reported in our published protocol [21] also influenced our choices. We kept notes of our reasons for including or excluding each study and resolved doubts about our judgements of study quality by discussing between ourselves. The processes of quality assessment and data extraction proceeded concurrently.

Data extraction, analysis and synthesis

For the purposes of data extraction, we followed the precedent of systematic reviews in a related area [20 22 28-30] and created a Microsoft Excel spreadsheet. VM initially extracted data from a sample of 10 studies. All members of the team reviewed and discussed the process, and agreed revisions to the data extraction form. VM then extracted data for all 46 studies using the revised data extraction form, which included:

- Study design, sample size, outcome data
- Educational levels of study participants (students vs practising health workers)
- How course material had been developed
- Topics covered
- Methods of teaching and learning
- Methods of evaluating outcomes including data collection tools
- Intervention type (e.g. workshops, curriculum designs)
- Durations of intervention
- Contexts of intervention (e.g. practising healthcare professionals, students)
- Mechanisms generated
- Learning outcomes

- Impacts (if any) of intervention on clinical outcomes
- Any theories or mechanisms postulated by author(s) explaining the effects of interventions

We read all 46 included studies twice, transferring relevant data into our data extraction form. We identified the context, mechanism, and outcomes and interactions between them for each study as well as the theory informing each intervention. To do that, we assumed that the design of each study was informed by a theory, which the authors stated explicitly or implicitly. Identifying those theories helped us understand how interventions worked to generate outcomes. We discussed and reflected on all the data we had identified (context, mechanism and outcome) for each study, sometimes using extracts of publication narratives to foster reflection.

The next stage was to identify themes that were common to different studies. Using an interpretative and narrative approach, we discussed and synthesised initial conclusions, which we used to refute or refine the candidate theories in our published protocol [21]. We chose this process of synthesis in preference to a metaanalysis, which would not have been possible given the diversity in study populations, designs, interventions, and outcomes [31].

RESULTS

General characteristics of the studies

Table 1 provides a summary of the 46 studies. Twenty-seven (59%) came from the USA; seven (19%) from Europe; four each from South America (all from Brazil) and Asia; two from Canada and one each from Africa (i.e. South Africa) and Australia. In total, 4816 participants participated in them (median = 76 participants; interquartile range: 47, 178). Interventions that had healthcare professionals as participants had somewhat larger numbers (median = 98; interquartile range (46, 163) than those having students as participants (median = 54 participants; interquartile range 32, 152).

The studies had varied study designs (shown in table 2) with a preponderance (n=39, 85%) of quasi-experimental designs. Twenty-one studies had follow-up evaluations after the pre-test and post-test evaluations. The time period between post-test and follow-up evaluations ranged between 2 weeks and 12 months.

Most studies (n=32, 70%) evaluated outcomes using surveys of knowledge, attitudes, self-reported practice behaviours, self-efficacy, confidence, and feedback. A large proportion of these surveys were developed by the authors, who did not usually report the psychometric properties of their instruments. All the interventions that set out to improve knowledge used multiple choice questions (ranging between 1 and 78 questions). Changes in attitude before and after interventions were assessed using Likert scales, anchored with statements describing attitudes.

Most questionnaires measuring behaviour changes used self-reported changes in nutrition practice behaviour. A few studies observed clinical behaviour to measure changes in nutrition practice. For example, one study in the Netherlands [32] used incognito standardized patients to assess the impact of an intervention on the nutrition practice behaviour of GP residents. Another study in Brazil [33] measured nutrition indices (i.e.wasting, stunting, and underweight) of children to determine the impact of an educational intervention that aimed to improve the provision of nutrition counselling to mothers and/or care givers by doctors.

Table 1: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Levy *et al* [34]	Workshop	US	Primary healthcare professionals (doctors, nurses, physician assistants)	Pre-and post-test without control group	Training programme to provide information, tools, and technical assistance to primary care practices to improve delivery of preventive services and the management of chronic diseases	• Training well received by all participants • Self-reported improvement in knowledge between pre-and post-test • Self-reported satisfaction with intervention
Carson [35]	Part of an ambulatory Clerkship	US	4th year medical students	Cross-sectional	• Training medical students on assessment of body composition using tape measure • Facilitating the identification and treatment of metabolic syndrome	• Increased self-reported knowledge • Probable changes in practice behaviour
Taren *et al* [36]	Required course	US	Preclinical medical students	Pre-and post-test with control group	• Evaluation of an integrated nutrition education program • Nutrition intervention for disease prevention and therapy	• Significant increase in nutrition OSCE scores between pre-and post-test • Increased self-reported satisfaction in nutrition content of the curriculum
Buckley [37]	Varied formats (web-based, web-enhanced and traditional lectures)	US	4th year nursing students	Cross-sectional	Evaluating the effect of various formats of training on the nutrition knowledge of participants	• No significant changes in knowledge between the three formats • More positive perception of web-enhanced than the web-based and traditional

Table 1 Continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ray *et al* [38]	Lectures, demonstrat-ions, and interactive practical sessions	UK	3rd and 4th year clinical students	Pre-and post-test without control group	• Evaluating the effectiveness of a nutrition education intervention in a cohort of tomorrow's doctors using knowledge, attitude and practice scores related to clinical nutrition • Covering topics relating to hospital malnutrition	• Significant improvement in knowledge scores between pre- and post-test • Significant changes in attitude scores • Students reported satisfaction with the course • Applied acquired knowledge to patients
Ke *et al* [39]	Workshop	Taiwan	Nurses in ICU, GI and GS	RCT	• The effects of educational intervention on nurses' knowledge, attitudes and behavioural intentions regarding supplying artificial nutrition and hydration • Coverage of topics such as normal nutrient metabolism, nutrient metabolism for terminal cancer patients, and appropriateness of supplying ANH to terminal cancer patients	• Significant improvement in knowledge between pre and post-test • Significant changes in mean attitude scores • Significant changes in behaviour intentions
Buchowski *et al* [40]	A computer-based and a required course	US	First year medical students	Pre-and post-test without control group	• The efficacy of 2 modules (Nutrition Anaemias and Diabetes and Weight Management) used by first year medical students • Coverage of topics such as nutritional anaemias, diabetes, and weight management	• Increase in knowledge scores between pre- and post-test • Developed positive attitudes towards nutrition after intervention • Mixed results with regard to confidence to counsel patients on nutrition

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Puoane *et al* [41]	Workshop	South Africa	Nurses	Pre-and post-test without control group	• Assessing the attitudes and perceptions towards severely malnourished children and their mothers/caregivers pre-and post-intervention • Coverage of topics such as principles of care set out by the WHO for managing severe malnutrition	• Positive change in attitudes towards malnourished children after intervention • Change in perceptions about malnourished children after training • Reduction in case fatalities
Hillenbrand and Larsen [42]	Workshop	US	Paediatric residents	Pre-and post-test without control group	The effect of an educational intervention on paediatric residents' knowledge about breastfeeding, their confidence in addressing lactation issues, and their management skills during clinical encounters with breastfeeding mothers.	• Intervention improved the knowledge of paediatric residents about breastfeeding • Confidence increased after the intervention • Limited changes in participants' practice behaviour after intervention
Maiburg [32]	Computer-based instruction	The Netherlands	GP trainees	Pre-and post-test with control group	• The impact of a computer-based instruction on nutrition knowledge and practice behaviour of general practitioner (GP) trainees. • Covered a wide range of nutrition including food pyramid, obesity, diabetes mellitus, hypercholesterolemia, hypertension, irritable bowel syndrome	• Improvement in knowledge scores after intervention • Changes in practice behaviour

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ockene *et al* [43]	Workshop	US	Internists	RCT	• Impact of a training programme on physicians' lipid intervention knowledge, attitudes and skills • Improved skills on brief dietary risk assessment and patient-centred counselling	• No significant changes in self-reported knowledge scores • Limited changes in attitudes • Counselling scores increased between pre and post-test
Zaman *et al* [44]	Workshop	Pakistan	Healthcare workers	RCT	Impact of training health workers in nutrition counselling in enhancing their communication skills and performance, improving feeding practices, and reducing growth faltering in children aged 6-24 months.	• Improved communication skills • Improved consultation performance • Mothers able to recall recommendations of health workers
Eisenberg *et al* [45]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	Improving healthcare professionals nutrition behavior, personal habits and their perceived ability to advise overweight or obese patients through the inclusion of 'culinary education' in the form of cooking demonstrations and participatory hands-on cooking workshops, combined with more traditional didactic, nutrition-related presentations	• Self-reported significant positive changes in ability to counsel obese patients • Changes in participants' nutrition behaviours

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Roche *et al* [46]	Computer-based instruction	US	Paediatric residents	RCT	A computer-based compact disc instructional program covering the nutrition topics of oral rehydration therapy, calcium, and vitamins.	• Modest improvement in self-reported knowledge scores after intervention • Positive attitudes towards computer instruction after intervention • Participants believed intervention enhanced their knowledge in nutrition
Gance-Cleveland [47]	Workshop	US	Nurse practitioners	Pre-and post-test without control group	• Four hour training session on Healthy Eating and Activity Together (HEAT) Clinical Practice Guideline (CPG) to improve provider behaviour and efficacy • Topics covered included obesity prevention, behaviour modifications and family counselling, family collaboration and advising	• Post training results revealed significant improvement in practitioner knowledge • Post training results revealed significant improvement in practitioners' intent to improve behaviour • Post training results revealed significant improvements in practitioners' report of increased confidence in ability to address barriers
Ray *et al* [48]	Workshop	UK	Junior doctors	Pre-and post-test without control group	Nutrition assessment in hospitalised patients	Significant improvement in knowledge, attitudes and practice scores

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Bassichetto and Rea [49]	Workshop	Brazil	Paediatricians and nutritionists	RCT	• Training intervention to equip junior doctors to run a hospital nutrition awareness week to contribute to the improvement in nutrition care • Topics covered included clinical and public health nutrition, organisational management and leadership strategies	• Significant improvement in knowledge scores after intervention • Improvement in dietary counselling after intervention
Dacey *et al* [50]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	• The impact of two types of live-face-to-face CME programs aiming to alter participants' thinking and behaviour and comfort with the use of lifestyle medicine • Topics included the history and rationale for lifestyle medicine, exercise medicine initiative, and lifestyle medicine competencies	• Improvement in the perception of barriers to lifestyle medicine • Improvement in self-reported knowledge • Increased confidence to counsel
Ritenbaugh *et al* [51]	4-year integrated nutrition curriculum	US	All levels of medical students	Cross-sectional	Evaluation of an integrated nutrition curriculum	• Changes in knowledge • Students satisfied with curriculum

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Tziraki and Graubard [14]	Workshop	US	Primary care doctors	RCT	• Training to improve the adoption of a manual to guide primary care practices in structuring their office environment and routine visits to improve nutrition screening, advice/referral, and follow-up for cancer prevention • Compared the effect of training on the manual with mailing the manual to practices	• Greater adoption of manual recommend-ations among practices in the training group • Training group adhered closer to diet screening recommendations in the manual • Changes in office environment were conducive to nutrition screening and dietary advice
Edwards and Wyles [52]	Workshop	UK	Healthcare professionals	Pre-and post-test without control group	Effectiveness of training sessions for health professionals concerning folic acid in pregnancy	• Improvement in knowledge after training • Participants enjoyed most parts of the training
Castro *et al* [53]	Workshop	Brazil	Doctors in the ICU	Pre-and post-test with control group	A multifaceted nutritional educational intervention on the quality of nutritional therapy and clinical outcomes of critically ill patients	• Significant improvement in participants' knowledge after the intervention • Reduction in patients' length of stay of in the ICU • Adequacy of nutritional therapy improved significantly • Initiating enteral nutrition earlier than 48 hours more commonly

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pelto *et al* [33]	Workshop	Brazil	Doctors	RCT	• Training to improve the nutrition counselling behaviour of physicians and caregiver retention of nutrition advice using the nutrition component of the WHO/UNICEF strategy of Integrated Management of Childhood Illness (IMCI) • Reducing growth faltering in children by means of the nutrition training program	• Modest changes in physician behaviour in practice • Mother's uptake of physician advice improved • Reduction in malnutrition cases
Kohlmeier *et al* [54]	Computer-based instruction	US	First year medical students	Pre- and post-test without control group	Evaluating students' attitudes and self-efficacy in nutrition and cancer and acceptability of a computer-based instruction	• Significant improvement in attitudes and self-efficacy after intervention • Students generally accepted computer-based instruction
Bjerrum [55]	Workshop	Denmark	Nurses	Pre-and post-test without control group	• Improving nurses knowledge in nutrition and their attitudes towards their responsibility to providing nutrition care in relation to assessment and management • Coverage of basic nutrition education, malnutrition in the hospital setting	• Changes in knowledge and attitudes • Participants felt more secure in their ability to provide nutrition care • Participants were satisfied with the intervention

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pedersen *et al* [56]	Workshop	Denmark	Nurses	Pre-and post-test without control group	Training programme to implement nutritional guidelines to change nurses' nutrition practice behaviour relating to the identification of patients' eating habits, improving patients' knowledge about appropriate food choices and number of snacks eaten between meals to risk of undernutrition in hospitalized patients.	• Modest changes in nutrition practice behaviour • Improvement in the eating difficulties of patients • Patients' knowledge of appropriate food choices improved
Conroy *et al* [57]	Required course	US	2nd year medical students	Pre-and post-test without control group	Impact of an innovative Preventive Medicine and Nutrition curriculum on students' confidence about addressing patients' diet and exercise patterns and on their own health habits	• Personal dietary, exercise patterns of participants improved • Confidence in their ability to address diet and exercise in patients increased
Endevelt, Shahar & Henkin [58]	Workshop	Israel	2nd year medical students	Cross-sectional	• Identification of time slots for nutrition training for medical students • Impact of a nutrition education programme on students' knowledge • Topics covered included nutrition and dietary recommendations for healthy people. Health risks of obesity	• Changes in knowledge • Students considered nutrition curriculum to be effective

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Olivarius *et al* [59]	Seminar	US	Primary care doctors	Pre-and post-test with control group	• Improving the quality of diet recording and instruction in primary care • Diet counselling for diabetes patients using one's own diet	• Improvement in personal dietary behaviours of participants • Changes in attitudes towards dietary counselling
Schlair *et al* [60]	Workshop	US	First year medical students	Pre-and post-test without control group	• The feasibility and impact of a brief nutrition-counselling curriculum on medical students' nutrition knowledge, confidence, attitudes and practices and their own affect the students' own nutrition behaviour and attitudes • Topics covered were nutrition-related counselling confidence for patients with obesity and chronic disease and understanding of simple nutrition messages	• Significant changes in self-efficacy scores • Significant changes in attitudes • Improvement in nutrition counselling competence • Improvement in personal dietary habits
Scolapio *et al* [61]	Workshop	US	Doctors, dieticians and pharmacist	Pre and post-test with control group	• Impact of a live continuing medical education nutrition course on participants' nutrition knowledge and practice behaviour. • Coverage of a variety of topics including identifying methods to feed patients with acute pancreatitis, parenteral nutrition, management of obesity, and others.	• Significant changes in knowledge • Confidence in counselling patients on nutrition improved • Modest changes in practice behaviours

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Kennelly *et al* [62]	Workshop	Ireland	GPs and nurses	Pre-and post-test without control group	The impact of a dietetics intervention on healthcare professionals' knowledge in nutrition and practice behaviour related to the management of malnutrition in hospitalized patients and the acceptability of the educational intervention	• Significant changes in knowledge • Modest changes in practice behaviours • Level of acceptance for the intervention increased
Lewis *et al* [63]	Internet-based instruction	US	Paediatric residents	Cross-sectional	• Evaluating paediatric trainees' engagement, knowledge acquisition and satisfaction with nutrition modules delivered in interactive and non-interactive format • Coverage of breastfeeding practices	• Significant change in knowledge • Engagement with course content increased • Level of satisfaction with intervention increased
Acuna *et al* [64]	Workshop	Brazil	Medical and nursing students	Pre-and post-test without control group	• Evaluating the effect of an intensive education course given to health care professionals and students • Topics covered related to hospital malnutrition	Ability to diagnose malnutrition improved
Powell-Tuck *et al* [65]	Required course	US	2nd year medical students	Pre-and post-test without control group	Development and inception of a 7-day curriculum on diet and health	• Students' feedback were positive • Significant changes in knowledge

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Afaghi *et al* [66]	Workshop	Iran	Clinical year 4 and 5 students	Pre-and post-test without control group	• Clinical based case study teaching to enhance clinical skills regarding the role of nutrition in chronic disease • Topics covered included the role of nutrition in chronic diseases, assessment of dietary intake and weight management	• Student perceptions of the adequacy of the instruction were positive • Significant changes in knowledge
Carson *et al* [67]	Required course	US	4th year medical students	Pre-post-test with control group	The outcomes of an integrated cardiovascular nutrition in the fourth year of medical school at the University of Texas	• Significant changes in knowledge • Significant changes in attitude • Self-efficacy in addressing nutrition issues improved
Vanderpool *et al* [68]	Continuous medical education	US	Paediatric gastroenterology residents and paediatric gastroenterologists	Pre-and post-test without control group	• Improving nutrition knowledge acquisition and dissemination. • Topics covered included paediatric nutrition and paediatric nutrition assessment	• Changes in knowledge • Changes in behavior • Changes in patient outcomes
Duerksen [69]	Clinical rotation	Canada	Second year medical students	Pre-and post-test without control group	Assessment of hospitalized patients' nutrition using the Subjective Global Assessment (SGA).	• Students correctly identified malnourished patients • Increased confidence in nutritional assessment
Engel *et al* [70]	Computer-based training as part of family practice clerkship rotation	US	Third year medical students	Pre-and post-test without control group	Knowledge and self-efficacy in prescribing diets for patients with diabetes	• Improved changes in knowledge • Improved changes in self-efficacy

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Richards & Mitchell [71]	Presentation by a dietitian to individual participants	Australia	GPs	Pre-and post-test without control group	Presentation of a nutrition manual and behaviour modification strategies	• Improved confidence to provide specific nutrition information and dietary recommendations • Increase in the use of the nutrition manual • Nutrition counselling of patients improved
Kipp [72]	Computer-based instruction	US	First year medical students	Pre-and post-test without control group	Evaluation of a computer-assisted instruction (CAI) module on food Guide Pyramid and dietary guidelines	• Students considered CAI as appropriate learning tool for nutrition concepts • Students satisfied with format • Changes in knowledge
Cooksey *et al* [73]	Computer-based instruction	US	Pre-clinical medical students	Cross-sectional	Evaluation of series of interactive, multimedia educational programs (Nutrition in Medicine) that teach the basic principles of nutritional science and application to cases	Advantages of accessibility, self-paced study, interactivity, immediate feedback, and tracking students' performance were noted
Cheatham *et al* [74]	Computer-based tutorial	US	Nursing, physician assistant and physical therapy students	Pre-and post-test without control group	Development and use of a computer-based tutorial on nutritional assessment	• Significant changes in knowledge scores • Students felt amount of content was adequate
Kolasa *et al* [75]	Workshop	US	Dietetic students, family medicine residents and third year medical students	Cross-sectional	Encouraging effective communication with both media and consumer through article preparation	Participants found the intervention to be an interesting way to learn about current food and nutrition issues
Fox [76]	Required course	Canada	Community nutrition graduate students	Pre-and post-test without control group	Incorporation of arts as strategies for understanding and addressing community health issues.	Students recognised the incorporation of arts as a mechanism of conducting health research, advocacy, education, healing, and capacity-building initiatives

RCT= Randomized Control Trial; GP=General Practitioner; ICU = Intensive Care Unit; GI= Gastroenterology and GS= General Surgery

Intervention focus, types, teaching and learning formats, duration of interventions and expected learning outcomes

Only 11 studies (24%) explicitly stated the theoretical underpinning of their interventions. These included experiential, social, and cognitive learning theories as well as cognitive theory of multimedia learning. The purpose of most interventions was to improve participants' competencies (i.e. knowledge, skills and attitudes) in a variety of nutrition topics (shown in table 1). Studies originating from developing countries tended to cover topics related to infant and young child feeding practices, whereas those from developed countries covered topics relating to hospital malnutrition and nutritional management of chronic diseases. Most studies in which students participated aimed to increase curriculum contact hours and nutrition content. Studies involving practitioners were usually continuing medical education (CME) programs aiming to improve knowledge, attitudes, skills, and practice behaviour in specific topics such as breastfeeding practices and dietary counselling.

Teaching and learning formats included lectures, problem-based learning tutorials, nutrition slogans, demonstrations, role plays, group discussions, games, and video presentations. All interventions used more than one teaching and learning format except six, which were either lecture-based or computer-based only. Almost all the interventions used innovative teaching and learning methods. Interventions involving students were usually obligatory and lasted from between two weeks to four years. Those involving professionals were generally shorter. The shortest intervention was a one-hour intensive session for general practitioners and other healthcare professionals on the benefits of giving folic acid to women of childbearing age [52]; the longest was a four year required course for medical students. Inconsistent reporting of the length of interventions (including use of terms like credit hours) made it difficult to determine mean and median lengths.

Table 2: Study designs and data collection methods

Characteristic	Frequency (%)
Study design	
Randomised control trials	7(15%)
Quasi-experimental	
Pre-test-post-test with control group	6(13%)
Pre-test-post-test without control group	26(57%)
Cross-sectional	7(15%)
Methodological approach	
Qualitative	5(10%)
Quantitative	32(70%)
Both qualitative and quantitative	9(20%)
Data collection method	
Questionnaires/surveys only	32(70%)
Observations only	2(4%)
Focus group discussions only	2(4%)
Questionnaires/survey with other methods (e.g. interviews, observations)	10(22%)
Format of intervention	
Training programs	13(28%)
Workshops	8(17%)
Required courses	7(15%)
Technology-based (computer-based, internet-based)	11(24%)
Ambulatory clinical rotations	2(4%)
Seminars	1(2%)
Continuing medical education programs	4(9%)
Healthcare professionals (n=22, 48%)	
Doctors (general practitioners/primary care)	8(36%)
Nurses	6(27%)
Multidisciplinary participants (e.g. nurses, doctors, pharmacists)	8(36%)
Students (n=24, 52%)	
Undergraduate, preclinical	14(58%)
Undergraduate, clinical	5(21%)
Postgraduate	5(21%)

Context-Mechanisms-Outcomes Configurations

Table 3 lists the contexts, mechanisms, and outcomes (CMOs). We describe here how those interacted to yield context-mechanisms-outcomes configurations (CMOCs).

Emphasizing skills development instead of knowledge outcomes ("Let me be skilful")

Researchers were often triggered to design interventions by professionals' lack of knowledge about nutrition. This was particularly true of undergraduate education [37 40 58 63 65 66], where all but one [52] of the interventions primarily targeting knowledge took place. Yet interventions that only aimed to improve knowledge were less likely to change practice behaviour. In four studies, for example, significant gains in knowledge did not predict practice scores [38], improve students' assessment of the nutrition status of overweight patients [35], influence behaviour change intentions [39], or affect dietary counselling for mothers/caregivers of children aged 12-24 months [49]. And there were interventions, which did not significantly increase knowledge yet changed behaviour. For example, a significant improvement in diet counselling during audiotaped physician-patient interactions [43 50] and increased self-reported counselling behaviour and confidence [50] took place without any significant increase in knowledge. In one study, Ockene et al [43] noted that 'a large proportion (1.5 hour) of the entire 3-hour CME training program was devoted to the learning of counselling and dietary assessment skills'. These findings show that it is important to train skills and create learning environments that encourage the acquisition of skills in order to change healthcare professionals' nutrition care behaviour [77 78].

Table 3: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Participants lacking nutrition counselling skills • Participants having inadequate knowledge • Participants being future and practising healthcare professionals	Emphasizing skills building instead of knowledge outcomes ("let me be skillful")	• Being more confident • Feeling adequately prepared	• Use of dietary counselling steps • Self-reported confidence to counsel patients and change in counselling behaviour
• Lack of faculty to provide nutrition training at both preclinical and clinical settings • Participants being future and practising healthcare professionals	Superiors role modelling the delivery of nutrition care ("I look up to you")	• Being more confident • Sense of acceptance • Sense of credibility • Anticipation of being valued	• Better delivery of nutrition care in clinical settings • Greater confidence in nutrition counselling
Participants being future and practising healthcare professionals	Meeting the needs of potential participants of an intervention ("Ask me what I want")	• Interest • Sense of knowing the needs of participants	• Greater satisfaction with educational intervention • Signicant gains in knowledge outcomes
• Participants lacking time to provide nutrition care • Lack of payment for providing preventive care • Participants having limited access to referral sources and materials for nutrition care • Poor investment into nutrition care • Lack of supportive office systems to deliver nutrition care • Separation of prevention and curative services in the health care system	Addressing structural and systemic factors to make an enabling environment ("Is my consulting room enabling?")	• Feeling comfortable to deliver nutrition care • Sense of acceptance • Perceiving fewer barriers to the delivery of nutrition care • Sense of Recognition	• Structured office environment conducive to providing nutrition-related services • Strategies to address lack of support systems • Encountering fewer barriers to lifestyle medicine

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Inadequate instruction and syllabi for nutrition training in curricula • Busy healthcare professionals lacking time to attend continuing education programs in nutrition	Incorporating technology-based education ("My computer is a learning tool")	• Convenience and self-paced study • Interactivity • Instant feedback • Accessibility	• Significant gains of knowledge • More positive attitudes towards nutrition care • Changed real-time practice behaviour • Greater confidence in skills of nutrition counselling • Better counselling skills
• Practising health care professionals • Participants lacking appropriate tools to deliver nutrition care • Participants' personal dietary and lifestyle habits • Participants having inadequate training in nutrition • Participants not routinely addressing patients' nutrition problems • Existence of structural barriers to providing nutrition care to patients	Providing participants with local, practical relevant tools and messages ("Give me tools")	• Removal of perceived barriers • Feeling comfortable	• Facilitating the uptake of nutrition messages • Changed nutrition practice behaviour • Engaging in specific rather than general discussion with patients • Giving relevant advice and recommendations to patients • Simplifying complex messages
Poor interest in nutrition education	Use of non-traditional teaching strategies ("Using the right strategy for the right job")	• Capture interest of participants • Meet the learning needs of participants • Active participation and uptake of knowledge and skills • Relevance of learning	• Engaging the management of malnutrition • Engaging in exercise and dietary counselling • Ability to counsel overweight/obese patients • Significant changes in knowledge gains • Positive personal health habits of participants

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Lack of confidence to deliver nutrition care • Among both future and practising healthcare professionals	Improving self-efficacy ("I feel that I can do it, so I will do it")	• Feeling motivated • Feeling confident	• Self-reported changes in practice behaviours • Intentions to change behaviour
• Participants having inadequate knowledge • Among both future and practising healthcare professionals • Participants lacking training in diet counselling • Lack of patient motivation to change dietary pattern • Lack of time	Improving the personal health habits of healthcare professionals ("Do as I do")	• Being more confident • Sense of being a role model • Sense of relatedness to patients	• Greater counselling confidence • Intentions to change behaviour • Positive healthy lifestyles • Engaging in dietary assessment • More favourable attitudes towards nutrition counselling
• Low priority given to nutrition • Inadequate time dedicated to nutrition • Healthcare students • Reported inadequate knowledge in nutrition	Integrating nutrition content ("Add nutrition to my learning")	• Accepting nutrition education • Reduction in perception of time limitations	• Greater recognition of the relevance of nutrition education • Increased in the number hours dedicated to nutrition • Greater gains in cognitive outcomes
• Multidisciplinary nature of healthcare delivery • Cross-disciplinary nature of nutrition	Adopting a multidisciplinary approach in intervention design and implementation ("Working with others")	• Sense of belonging • Acceptance • Recognising the multidisciplinary nature of nutrition healthcare delivery	• Multi-disciplinary designed program • Meets the needs of all participants • Greater satisfaction

Superiors role modelling the delivery of nutrition care ("I look up to you")

A candidate theory in our published protocol [21], that healthcare professionals would be more likely to deliver nutrition care if they saw their superiors model the same behaviour, was apparent in the evidence. Seeing superiors model nutrition care led research participants to feel more confident, accepted, and credible. They anticipated their actions being valued, which led them towards changing their nutrition practice. Virtual physician mentors [40], simulation of GP consultations using video clips [32], physicians describing how they addressed nutrition in practice, and role modelling by physicians in classes [79] were among the interventions which provided positive role modelling.

Meeting the needs of potential participants of an intervention ("Ask me what I want")

Most interventions were modelled on the theory that education will be most successful when it is designed to meet participants' needs [61]. Needs assessment identified gaps in learners' knowledge or practice behaviour [61], and how they learned best. It informed the content, format, and design of curricula. It helped select teaching and learning methods to which participants were receptive, which they found interesting and satisfying, and which led them to value their education.

Addressing structural and systemic factors ("Is my consulting room enabling")

As well as education, interventions that improved working environments influenced participants' behaviour and helped maintain changes that had been achieved [56]. Eight studies helped participants address lack of support [47] and practical barriers [50]. They restructured office environments to make them more conducive to providing nutrition care [14]. Pelto et al [33], for example, stated that 'structural conditions in the public health system in Pelotas provided an environment in which physicians could utilize their knowledge'. Other researchers provided nutritional messages that busy primary care providers could deliver to patients [34]. Presentations on change management and leadership [48] and provision of guidelines on office organization [14] helped improve nutrition care. Collaboration between education and care delivery leaders helped remove structural and systemic barriers.

Incorporating technology-based education ("My computer is a learning tool")

Seven studies used technology to resolve problems caused by busy healthcare professionals having insufficent time to attend continuing education programs, programs having inadequate nutrition content, and faculty being unavailable to teach. Computer-based and internet-based interventions allowed easy updating of content [32], permitted self-directed and independent study of nutrition information [32 46], presented content consistently [79], were accessible [73], promoted interactivity [73], and were convenient for participants because they were self-administered [32 79] and self-paced [73]. These interventions led to significant gains of knowledge [40 46 54 63], positive attitudes [32 46], increase in self-assessed nutrition counselling skills [32 54], and real-time practice behaviour [32]. The convenience, interest, and independent nature of this type of education contributed to those outcomes.

Providing participants with local, practically relevant tools and messages ("Give me tools")

Some researchers theorised that making local, practically relevant tools and messages available in practice contexts would change the behaviour of trainee healthcare professionals. The tools they provided included memorable slogans [34], simple 'key take home messages' [34 38 41 62], personalized nutrition messages [34], and locally relevant examples [33]. Researchers simplified nutrition messages [34], provided resource materials and tools to resolve problems in counselling and assessing patients [33 62], and adapted advice for local conditions [33]. Those interventions helped professionals engage in specific rather than generic discussions with patients, and provide advice and recommendations that patients found relevant [33]. The authors of a randomized controlled trial, which improved physicians' counselling of mothers with malnourished children aged 12-24 months in Brazil [33], attributed children's improved nutritional status to this provision of locally appropriate messages and tools.

Using non-traditional teaching strategies ("The right strategy for the right job")

Another theory, which guided interventions, was that non-traditional teaching and learning strategies would change professionals' behaviour. For instance, Hillenbrand et al 2002 [42] hypothesized that providing a series of interactive educational interventions to paediatric residents would increase their knowledge about breastfeeding and lactation problems and increase their confidence to counsel breastfeeding women. Interventions, which sometimes complemented lectures, included discussions, simulated patient cases, group work, role plays, hands-on demonstrations, group practice, panel discussions and case-based learning. Other interventions included problem-based learning tutorials, computer or web-based cases, student-led debates, self-assessment exercises, and clinical case presentations. These interventions provided practical experience and promoted active learning. They emphasised the development of skills rather than just knowledge. They engaged participants' interest and helped them assume responsibility for their own learning. These interventions caused significant changes in participants' knowledge, personal health habits, confidence to provide exercise and dietary counselling, ability to counsel obese patients, and ability to manage malnutrition. Carson et al 2002 [79] attributed the enhanced nutrition counselling skills of students in a four week ambulatory care rotation to their innovative combination of teaching strategies.

Improving self-efficacy ("I feel that I can do it, so I will do it")

Self-efficacy is a basic tenet of Bandura's social learning theory [80]. This term describes individuals' confidence in their ability to perform a task or achieve an outcome. It is a key influence on behaviour [80]. Eight studies explicitly set out to improve participants' self-efficacy by increasing their confidence. They adopted strategies like role modelling by practising physicians [79], role playing using either simulated or real patients [42 43 47 57], providing demonstrations and hands on practice sessions [34 42 43 45 47 60 79], and viewing then discussing videos and web-based cases [43 67]. Four each of these interventions were conducted among future healthcare professionals and practising healthcare professionals. They were effective in both settings.

Improving the personal health habits of the healthcare professional ("Do as I do")

Four interventions, which stimulated practising [45 59] and student [57 60] healthcare professionals to take better care of their own health, had positive outcomes. These included regular consumption of fruits and vegetables, personal awareness of calorie consumption, engaging in regular physical activity, and developing culinary skills. In both settings, these led to better self-reported healthy lifestyles and self-reported ability to undertake dietary assessment [60], counselling confidence [45 57 60], self-assessed knowledge [59] and even to treating a higher proportion of diabetic patients with diet alone [59]. Healthcare professionals, who considered themselves role models for patients, felt more confident to advise patients to do as they had done.

Initial and revised programme theory

Our published protocol [21] presented candidate and programme theories, and a theoretical model, which we briefly repeat here. Drawing on social cognitive theory, we postulated that:

- Healthcare professionals' ability to deliver nutrition care is influenced by their competence, which is the outcome of a learning process, which is influenced by factors within academic environments. Those factors include the quantity and quality of nutrition content in curricula, the teaching and learning methods employed, and the extent to which learning is reinforced.
- Professionals are more likely to care for patients' nutrition if they have high self-efficacy for nutrition care and vice versa.
- Professionals' delivery of nutrition care is a behaviour demonstrated in the social context of workplaces, which is influenced by observing and modelling the behaviours, attitudes and emotional reactions of others (e.g. superiors) [81]. It is also influenced by the structural determinants of behaviours such as the workplace settings themselves (e.g.

hospital/community, emergency/paediatric/general ward), job descriptions/role, time and availability of other staff to undertake particular roles.

The review process described above tested those theories, which led us to revise, add components to, and broaden our theoretical model (shown in figure 2). 'Outcomes', in realist terminology, can be short, medium and long-term [82]. We have added a hierarchy of outcomes to our theoretical model.

The items in the model are interrelated and inter-linked as opposed to operating in isolation from one another. They do not operate in a linear fashion. And a single intervention can generate several context-mechanism-outcome configurations. This is exemplified by assessment of educational needs. This is carried out to identify knowledge, skills and attitude gaps and other educational needs of potential participants. The outcome of the needs assessment informs the design of the educational intervention as well as its characteristics. It informs what kind of strategies (characteristics) the intervention should have in order to realise the desired outcome. These strategies could include improving the personal health habits of healthcare professionals, adopting technology-based education, improving skills development, adopting innovative teaching and learning strategies, role modelling, and others. These will generate mechanisms (not indicated in the diagram) such as interest, receptivity, and acceptance, which will generate short-term outcomes such as improved knowledge, attitude, skills, self-efficacy, values and personal habits. But then these may only be translated into more effective nutrition practice behaviour (medium-term outcomes) if there is an enabling environment (context) in which to demonstrate such behaviour.

Longer-term change may require more fundamental alternations to practice contexts such as restructuring the healthcare system, adopting favourable policies, providing appropriate tools to deliver nutrition care, investing in preventive care, and providing working environments, which are conducive to good care. Better delivery of nutrition care to patients will result in the long-term goal of improving patients' clinical outcomes.

=Insert figure 2=

We present in table 4 a summary of the characteristics of interventions in accordance with what works, for whom, and under what conditions.

Table 4: Overview of what works, for whom, under what circumstances, to achieve what?

What works	Choosing interventions, which are educationally and clinically relevant to the needs of participants Adopting appropriate teaching and learning techniques Building on self-efficacy and confidence through role modelling Emphasizing skills development rather than pure knowledge gains Improving the personal lifestyle habits of healthcare professionals Removing systemic barriers and restructuring healthcare systems Using practical, relevant tools Using Information and Communications Technology (computer-based education)
For whom	Doctors and other practising healthcare professionals Students of the health professions
Under what circumstances	Within a multidisciplinary approach Supported by both educational and care delivery leaders Where nutrition care is recognized as an important component of: Care delivery systems Curricula Where healthcare system are structured to be conducive to the practice of nutrition care
To achieve what outcomes	Achievement of both educational and clinical outcomes Sustainability of educational outcomes in clinical settings

Measurement issues

The ultimate aim of health education interventions is to improve health outcomes. Few studies, however, even tried to show improvements in patients' health because it is very difficult to do. Authors acknowledged that this limited the conclusions they could draw from their evidence (for example [61]), which meant they could often only speculate on how their interventions might affect patients' health. The impact of educational interventions is often ranked according to its position in Miller's pyramid of assessment [83]. Some studies achieved the highest level - the performance level – which is most likely to impact patient outcomes. They did so by directly observing the delivery of nutrition care in clinical settings [14 33 42 44 49], recording videos of doctors counselling patients [14], auditing charts [41 64 79], and using incognito simulated patients [32]. Most studies were at lower levels of the pyramid. For example, they assessed participants' reported changes in practice behaviours by means of self-administered surveys. As observed by the authors of one such studied [57], reliance on students' self-reported confidence in counselling rather than an objective measure of counselling skills (such as an objective structured clinical examination) limits the generalizability of the findings. Schlair et al [60] acknowedged the potential for social desirability bias in self-reports. Whilst self-report would be invalid evidence in a systematic review or meta-analysis, it is safer to use it in realist synthesis, which aims to produce progressively more refined theories of change rather than incontrovertible evidence.

For future studies, Scholapio et al [61] suggested that 'harder' data could be obtained using patient surveys and chart reviews, or having participants give specific examples of improved patient outcome that were directly linked to competences they had acquired from educational interventions. Our review shows the need for future studies to explore innovative ways of collecting this information [61].

DISCUSSION

The CMOCs identified in this realist review are preliminary and non-exhaustive and should be considered as a set of generic hypotheses derived from best available evidence. Nonetheless, they provide information to policy makers about what may improve the nutrition practice behaviour of healthcare professionals, how, under what conditions, and in what settings. Our review has identified a set of conditions that facilitate the success of interventions in varied contexts.

A key finding of this review is that improving the skills, self-efficacy, and attitudes of learners by adopting appropriate teaching and learning strategies is critical to the success of nutrition education interventions. Improving learners' skills and attitudes provides them with confidence and a sense of enactive mastery of the specific tasks they have to perform. Role modelling of the delivery of nutrition care by superiors, providing appropriate physical space in which to deliver nutrition care, and adopting favourable policies are important because they increase professionals' sense of being accepted, , credibility, relatedness, and assurance.

Our analysis shows that planners of educational interventions would be well advised to assess potential participants' needs and interests. Computer based education presents new opportunities for course designers and planners. Already considered as a potentially efficient form of teaching and learning in the health professions [46 84-86], this presents novel ways of incorporating nutrition content into healthcare professional curricula. Given that healthcare professionals say they have too little time to attend training programs and provide nutrition care, the convenience of computer-and internet-based education has potential to overcome barriers to learning.

The main strengths of our review were its integrative nature and our use of a methodology, which generated practical theories for future testing and implementation. The review had limitations. One is that we did not consult individual experts in the field when we developed our initial model. Had we done that, we might have included more candidate theories. We also acknowledge the interpretive and subjective nature of qualitative research and the likelihood that a different team of researchers might have arrived at different candidate program theories. We acknowledge limitations in the evidence base. The synthesis which results from any review is only as good as the primary studies it is able to include. Many of the primary studies provided limited, superficial descriptions of their educational interventions. This made it difficult for us to test all components of our candidate theories and to provide rich descriptions of some of the mechanisms that were identified. As has been found by other reviewers in medical education [22 28 29], this review was limited by a lack of descriptions of the contexts of the intervention, implementation processes, and mechanisms.

Other limitations included the unavailability of the full text of seven studies. Whilst it is a limitation, realist synthesis is less dependent on the inclusion of complete sets of studies than, for example, traditional systematic reviews. So, it may limit the scope of our findings but does not invalidate them. Whilst the backbone of metaanalysis and traditional systematic review is aggregation, realist synthesis refines theories by obtaining a rich (rather than necessarily complete) evidence-base of reports of how interventions generate certain pattern of outcome [82]. Finally, initial screening by just one author might be seen as a limitation but we found such high consistency between that author's judgement and a second author in a pilot phase of the project that we judged single-screening to make best use of the inevitably limited resources in the country, where the research was conducted.

We conclude that it has been possible to assemble, from a heterogeneous database, some patterns in the links between conditions, mechanisms, and outcomes that are consistent enough to guide the practice of nutrition education. Our findings have refined some existing candidate theories, which researchers, also, apply to their work on nutrition education.

ACKNOWLEDGEMENT
The authors wish to thank Mr. Fuseini Abdulai Braimah, senior library assistant, School of Medicine and Health Sciences, University for Development Studies, Ghana for his support in helping to retrieve full texts of some of the included studies.

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

COMPETING INTEREST
None

Contributors: VM and TD were responsible for the conception and design of the study. VM was principally responsible for searching, sourcing and initial screening of studies. VM, MGC and TD further screened studies based on abstracts. Quality assessment was done by VM, AS, FS and MGC. VM was responsible for data extraction, synthesis and interpretation of the data and drafting of the manuscript. AS, TD, FS, MGC and PA contributed to interpretation of the data and revision of the article. All authors approved the article for publication.

PROVENANCE AND PEER REVIEW: Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT: No additional data available.

REFERENCES
1. Pearson TA, Blair SN, Daniels SR, et al. AHA guidelines for primary prevention of cardiovascular disease and stroke: 2002 update consensus panel guide to comprehensive risk reduction for adult patients without coronary or other atherosclerotic vascular diseases. Circulation 2002;**106**(3):388-91
2. Bantle JP, Wylie-Rosett J, Albright AL, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2008;**31**:S61-S78
3. Goldstein LB, Adams R, Alberts MJ, et al. Primary Prevention of Ischemic Stroke A Guideline From the American Heart Association/American Stroke Association Stroke Council: Cosponsored by the Atherosclerotic Peripheral Vascular Disease Interdisciplinary Working Group; Cardiovascular Nursing Council; Clinical Cardiology Council; Nutrition, Physical Activity, and Metabolism Council; and the Quality of Care and Outcomes Research Interdisciplinary Working Group: The American Academy of Neurology affirms the value of this guideline. Stroke 2006;**37**(6):1583-633
4. United Nations Children's Fund. Improving Child Nutrition:The achievable imperative for global progress. In: Fund UNCs, ed. New York, 2013:1-124.
5. Kopelman P, Lennard-Jones J. Nutrition and patients: a doctor's responsibility. Clinical Medicine 2002;**2**(5):391-94
6. Council GM. Tomorrow's doctors: Outcomes and standards for undergraduate medical education. Manchester, UK: General Medical Council 2009
7. Abid A, Galuska D, Khan L, Gillespie C, Ford E, Serdula M. Are healthcare professionals advising obese patients to lose weight? A trend analysis. MedGenMed: Medscape general medicine 2004;**7**(4):10-10
8. Tsai AG, Wadden TA. Treatment of obesity in primary care practice in the United States: a systematic review. Journal of general internal medicine 2009;**24**(9):1073-79

9. Abramson S, Stein J, Schaufele M, Frates E, Rogan S. Personal exercise habits and counseling practices of primary care physicians: a national survey. Clinical Journal of Sport Medicine 2000;**10**(1):40-48
10. Huang J, Yu H, Marin E, Brock S, Carden D, Davis T. Physicians' weight loss counseling in two public hospital primary care clinics. Academic Medicine 2004;**79**(2):156-61
11. Laschinger HKS, Tresolini CP. An exploratory study of nursing and medical students health promotion counselling self-efficacy. Nurse Education Today 1999;**19**(5):408-18 doi: 10.1054/nedt.1999.0326[published Online First: Epub Date]|.
12. Jay M, Gillespie C, Ark T, et al. Do internists, pediatricians, and psychiatrists feel competent in obesity care? Journal of general internal medicine 2008;**23**(7):1066-70
13. Foster GD, Wadden TA, Makris AP, et al. Primary care physicians' attitudes about obesity and its treatment. Obesity Research 2003;**11**(10):1168-77
14. Tziraki C, Graubard BI, Manley M, Kosary C, Moler JE, Edwards BK. Effect of Training on Adoption of Cancer Prevention Nutrition-Related Activities by Primary Care Practices: Results of a Randomized, Controlled Study. Journal of general internal medicine 2000;**15**(3):155-62
15. McLaren DS. Nutrition in medical schools: a case of mistaken identity. American Journal of Clinical Nutrition 1994;**59**(5):960-3
16. Weinsier RL. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1995: medical-nutrition education--factors important for developing a successful program. American Journal of Clinical Nutrition 1995;**62**(4):837-40
17. Gershoff SN. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1996: nutrition education--success or failure? American Journal of Clinical Nutrition 1996;**64**(5):809-12
18. Ball EL, Hughes MR, Leveritt DM. Nutrition in general practice: role and workforce preparation expectations of medical educators. Australian Journal of Primary Health 2010;**16**(4):304-10
19. Mechanic D. Social research in health and the American sociopolitical context: the changing fortunes of medical sociology. Social Science and Medicine 1993;**36**(2):95-102
20. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Nutrition training improves health workers' nutrition knowledge and competence to manage child undernutrition: a systematic review. Frontiers in Public Health 2013;**1**
21. Mogre V, Scherpbier A, Dornan T, Stevens F, Aryee PA, Cherry MG. A realist review of educational interventions to improve the delivery of nutrition care by doctors and future doctors. Systematic reviews 2014;**3**(1):148
22. Wong G, Greenhalgh T, Pawson R. Internet-based medical education: a realist review of what works, for whom and in what circumstances. BMC medical education 2010;**10**(1):12
23. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist synthesis: An introduction: ESRC Research methods programme, University of Manchester. RMP Methods Paper 2004;**2**
24. McCormack B, Rycroft-Malone J, DeCorby K, et al. A realist review of interventions and strategies to promote evidence-informed healthcare: a focus on change agency. Implementation science 2013;**8**(1):107
25. Pawson R. *Evidence-based policy: A realist perspective*: Sage, 2006.
26. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist review–a new method of systematic review designed for complex policy interventions. Journal of health services research & policy 2005;**10**(suppl 1):21-34
27. Westhorp G, Walker B, Rogers P, Overbeeke N, Ball D, Brice G. Enhancing community accountability, empowerment and education outcomes in low and middle-income countries: A realist review. EPPI-Centre, Social Science Research Unit, Institute of Education, University of London 2014

28. Yardley S, Cottrell E, Rees E, Protheroe J. Modelling successful primary care for multimorbidity: a realist synthesis of successes and failures in concurrent learning and healthcare delivery. BMC Family Practice 2015;**16**(1):23
29. Jones AC, Shipman SA, Ogrinc G. Key characteristics of successful quality improvement curricula in physician education: a realist review. BMJ quality & safety 2015;**24**(1):77-88
30. Steinert Y, Mann K, Centeno A, et al. A systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education: BEME Guide No. 8. Medical teacher 2006;**28**(6):497-526
31. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ 2015;**349**:g7647
32. Maiburg BHJ, Rethans JE, Schuwirth LWT, Mathus-Vliegen LMH, van Ree JW. Controlled trial of effect of computer-based nutrition course on knowledge and practice of general practitioner trainees. American Journal of Clinical Nutrition 2003;**77**(4S):1019S-24
33. Pelto GH, Santos I, Gonçalves H, Victora C, Martines J, Habicht J-P. Nutrition counseling training changes physician behavior and improves caregiver knowledge acquisition. The Journal of nutrition 2004;**134**(2):357-62
34. Levy J, Harris J, Darby P, Sacks R, Dumanovsky T, Silver L. The primary care nutrition training program: An approach to communication on behavior change. Health Promotion Practice 2011;**12**(5):761-68
35. Carson JAS. Pocket tape measure for waist circumference: Training medical students and residents on a simple assessment of body composition. Journal of Nutrition 2003;**133**(2):547S-49S
36. Taren DL, Thomson CA, Koff NA, et al. Effect of an integrated nutrition curriculum on medical education, student clinical performance, and student perception of medical-nutrition training. American Journal of Clinical Nutrition 2001;**73**(6):1107-12
37. Buckley KM. Evaluation of classroom-based, Web-enhanced, and Web-based distance learning nutrition courses for undergraduate nursing. Journal of Nursing Education 2003;**42**(8):367-70
38. Ray S, Udumyan R, Rajput-Ray M, et al. Evaluation of a novel nutrition education intervention for medical students from across England. BMJ Open 2012;**2**(1) doi: e00041710.1136/bmjopen-2011-000417[published Online First: Epub Date]|.
39. Ke L-S, Chiu T-Y, Hu W-Y, Lo S-S. Effects of educational intervention on nurses' knowledge, attitudes, and behavioral intentions toward supplying artificial nutrition and hydration to terminal cancer patients. Supportive care in cancer 2008;**16**(11):1265-72
40. Buchowski MS, Plaisted C, Fort J, Zeisel SH. Computer-assisted teaching of nutritional anemias and diabetes to first-year medical students. American Journal of Clinical Nutrition 2002;**75**(1):154-61
41. Puoane T, Sanders D, Ashworth A, Ngumbela M. Training nurses to save lives of malnourished children. Curationis 2006;**29**(1):73-78
42. Hillenbrand KM, Larsen PG. Effect of an educational intervention about breastfeeding on the knowledge, confidence, and behaviors of pediatric resident physicians. Pediatrics 2002;**110**(5) doi: e5910.1542/peds.110.5.e59[published Online First: Epub Date]|.
43. Ockene JK, Ockene IS, Quirk ME, et al. Physician training for patient-centered nutrition counseling in a lipid intervention trial. Preventive Medicine: An International Journal Devoted to Practice and Theory 1995;**24**(6):563-70
44. Zaman S, Ashraf RN, Martines J. Training in complementary feeding counselling of healthcare workers and its influence on maternal behaviours and child growth: a cluster-randomized controlled trial in Lahore, Pakistan. Journal of health, population, and nutrition 2008;**26**(2):210

45. Eisenberg DM, Miller AM, McManus K, Burgess J, Bernstein AM. Enhancing medical education to address obesity:"See one. Taste one. Cook one. Teach one.". JAMA Internal Medicine 2013;**173**(6):470-72
46. Roche PL, Ciccarelli MR, Gupta SK, Hayes BM, Molleston JP. Multi-School Collaboration to Develop and Test Nutrition Computer Modules for Pediatric Residents. Journal of the American Dietetic Association 2007;**107**(9):1586-89 doi: http://dx.doi.org/10.1016/j.jada.2007.06.008[published Online First: Epub Date]|.
47. Gance-Cleveland B, Sidora-Arcoleo K, Keesing H, Gottesman MM, Brady M. Changes in nurse practitioners' knowledge and behaviors following brief training on the healthy eating and activity together (HEAT) guidelines. Journal of Pediatric Health Care 2009;**23**(4):222-30
48. Ray S, Laur C, Douglas P, et al. Nutrition education and leadership for improved clinical outcomes: training and supporting junior doctors to run 'Nutrition Awareness Weeks' in three NHS hospitals across England. BMC medical education 2014;**14**(1):109
49. Bassichetto KC, Réa MF. Infant and young child feeding counseling: an intervention study. Jornal de pediatria 2008;**84**(1):75-82
50. Dacey M, Arnstein F, Kennedy MA, Wolfe J, Phillips EM. The impact of lifestyle medicine continuing education on provider knowledge, attitudes, and counseling behaviors. Medical teacher 2013;**35**(5):e1149-e56
51. Ritenbaugh CK, Thomson CA, Taren D, et al. Nutrition curriculum in medical education: An integrated and comprehensive approach. Teaching and Learning in Medicine 1996;**8**(2):102-10
52. Edwards L, Wyles D. The folic acid message–can training make a difference? Journal of Human Nutrition and Dietetics 1999;**12**(4):317-26
53. Castro MG, Pompilio CE, Horie LM, Verotti CCG, Waitzberg DL. Education program on medical nutrition and length of stay of critically ill patients. Clinical Nutrition 2013;**32**(6):1061-66 doi: http://dx.doi.org/10.1016/j.clnu.2012.11.023[published Online First: Epub Date]|.
54. Kohlmeier M, Althouse L, Stritter F, Zeisel SH. Introducing cancer nutrition to medical students: effectiveness of computer-based instruction. American Journal of Clinical Nutrition 2000;**71**(4):873-77
55. Bjerrum M, Tewes M, Pedersen P. Nurses' self-reported knowledge about and attitude to nutrition–before and after a training programme. Scandinavian Journal of Caring Sciences 2012;**26**(1):81-89
56. Pedersen PU, Tewes M, Bjerrum M. Implementing nutritional guidelines–the effect of systematic training for nurse nutrition practitioners. Scandinavian Journal of Caring Sciences 2012;**26**(1):178-85
57. Conroy MB, Delichatsios HK, Hafler JP, Rigotti NA. Impact of a preventive medicine and nutrition curriculum for medical students. American Journal of Preventive Medicine 2004;**27**(1):77-80 doi: http://dx.doi.org/10.1016/j.amepre.2004.03.009[published Online First: Epub Date]|.
58. Endevelt R, Shahar DR, Henkin Y. Development and implementation of a nutrition education program for medical students: A new challenge. Education for Health: Change in Learning & Practice 2006;**19**(3):321-30
59. de Fine Olivarius N, Palmvig B, Andreasen AH, Thorgersen JT, Hundrup C. An educational model for improving diet counselling in primary care A case study of the creative use of doctors' own diet, their attitudes to it and to nutritional counselling of their patients with diabetes. Patient Education and Counseling 2005;**58**(2):199-202
60. Schlair S, Hanley K, Gillespie C, et al. How medical students' behaviors and attitudes affect the impact of a brief curriculum on nutrition counseling. Journal of Nutrition Education and Behavior 2012;**44**(6):653-57

61. Scolapio JS, Dibaise JK, Schwenk WF, 2nd, Macke ME, Burdette R. Advances and controversies in clinical nutrition: the education outcome of a live continuing medical education course. Nutrition in Clinical Practice 2008;**23**(1):90-95
62. Kennelly S, Kennedy N, Rughoobur G, Slattery CG, Sugrue S. An evaluation of a community dietetics intervention on the management of malnutrition for healthcare professionals. Journal of Human Nutrition and Dietetics 2010;**23**(6):567-74
63. Lewis KO, Frank GR, Nagel R, et al. Pediatric trainees' engagement in the online nutrition curriculum: preliminary results. BMC medical education 2014;**14**(1):190
64. Acuna K, Pires C, Santos G, et al. Detection of nosocomial malnutrition is improved in Amazon region by a standard clinical nutrition education program. Nutricion Hospitalaria 2008;**23**(1):60-67
65. Powell-Tuck J, Summerbell C, Holsgrove G, Garrow J. Four years' experience of an undergraduate medical nutrition course. Journal of the Royal Society of Medicine 1997;**90**(2):67-72
66. Afaghi A, Mohamadi AAHA, Ziaee A, Sarchami R. Effect of an Integrated Case-based Nutrition Curriculum on Medical Education at Qazvin University of Medical Sciences, Iran. . Global journal of health science 2012;**4**(1):112
67. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition education. American Journal of Preventive Medicine 2002;**23**(4):296-302
68. Vanderpool C, Lin HC, Scheimann A. NASPGHAN Nutrition University as a Model for Continuing Education Within Pediatric Nutrition. Journal of Pediatric Gastroenterology and Nutrition 2014;**58**(4):469-71
69. Duerksen DR. Teaching medical students the subjective global assessment. Nutrition 2002;**18**(4):313-15 doi: http://dx.doi.org/10.1016/S0899-9007(01)00801-2[published Online First: Epub Date]|.
70. Engel SS, Crandall J, Basch CE, Zybert P, Wylie-Rosett J. Computer-assisted diabetes nutrition education increases knowledge and self-efficacy of medical students. Diabetes Educator 1997;**23**(5):545-49
71. Richards D, Mitchell G. Insight. GPs and nutrition: what they want and how they want it. A GP nutrition education project. Australian Journal of Nutrition & Dietetics 2001;**58**(1):56-59
72. Kipp DE. Technological methods in nutrition education. Developing interactive computerized modules accessible on the World Wide Web for medical students. Topics in Clinical Nutrition 1997;**12**(2):38-44
73. Cooksey K, Kohlmeier M, Plaisted C, Adams K, Zeisel SH. Getting nutrition education into medical schools: a computer-based approach. American Journal of Clinical Nutrition 2000;**72**(3):868S-76S
74. Cheatham M, Boosalis MG, Boissonneault GA. Use of a Computer Tutorial on Nutritional Assessment by Three Different Groups of Health Professions Students. Journal of Allied Health 2002;**31**(4):252-55
75. Kolasa KM, Elesha-Adams M, Patton DD. When a reporter calls: media training to teach nutrition education. Topics in Clinical Nutrition 1996;**11**(4):75-80
76. Fox AL. Evaluation of a Pilot Arts and Health Module In a Graduate Community Nutrition Program. Canadian Journal of Dietetic Practice and Research 2009;**70**(2):81-86 doi: 10.3148/70.2.2009.81[published Online First: Epub Date]|.
77. Ockene JK, Kristeller J, Goldberg R, et al. Increasing the efficacy of physician-delivered smoking interventions. Journal of general internal medicine 1991;**6**(1):1-8
78. Bandura A. Social learning theory. Englewood Cliffs, New Jersey: Prentice-Hall 1977
79. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition eduction. American Journal of Preventive Medicine 2002;**23**(4):296-302 doi: http://dx.doi.org/10.1016/S0749-3797(02)00518-4[published Online First: Epub Date]|.

80. Bandura A. *Self-efficacy: The exercise of control*: Macmillan, 1997.
81. Bandura A. Social cognitive theory: An agentic perspective. Annual review of psychology 2001;**52**(1):1-26
82. Westhorp G, Walker B, Rogers P. Under what circumstances does enhancing community accountability and empowerment improve education outcomes, particularly for the poor? A realist synthesis protocol. London: EPPI-Centre. Social Science Research Unit, Institute of Education, University of London 2012
83. Miller GE. The assessment of clinical skills/competence/performance. Academic Medicine 1990;**65**(9):S63-7
84. Devitt P, Palmer E. Computer-aided learning: an overvalued educational resource? Medical education 1999;**33**(2):136-39
85. Carr MM, Reznick RK, Brown DH. Comparison of computer-assisted instruction and seminar instruction to acquire psychomotor and cognitive knowledge of epistaxis management. Otolaryngology--Head and Neck Surgery 1999;**121**(4):430-34
86. D'Alessandro DM, Kreiter CD, Erkonen WE, Winter RJ, Knapp HR. Longitudinal follow-up comparison of educational interventions: multimedia textbook, traditional lecture, and printed textbook. Academic radiology 1997;**4**(11):719-23

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2, 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4, 5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4, 5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4, 5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6-28
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	NA
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	NA
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	29
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	29
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	29
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

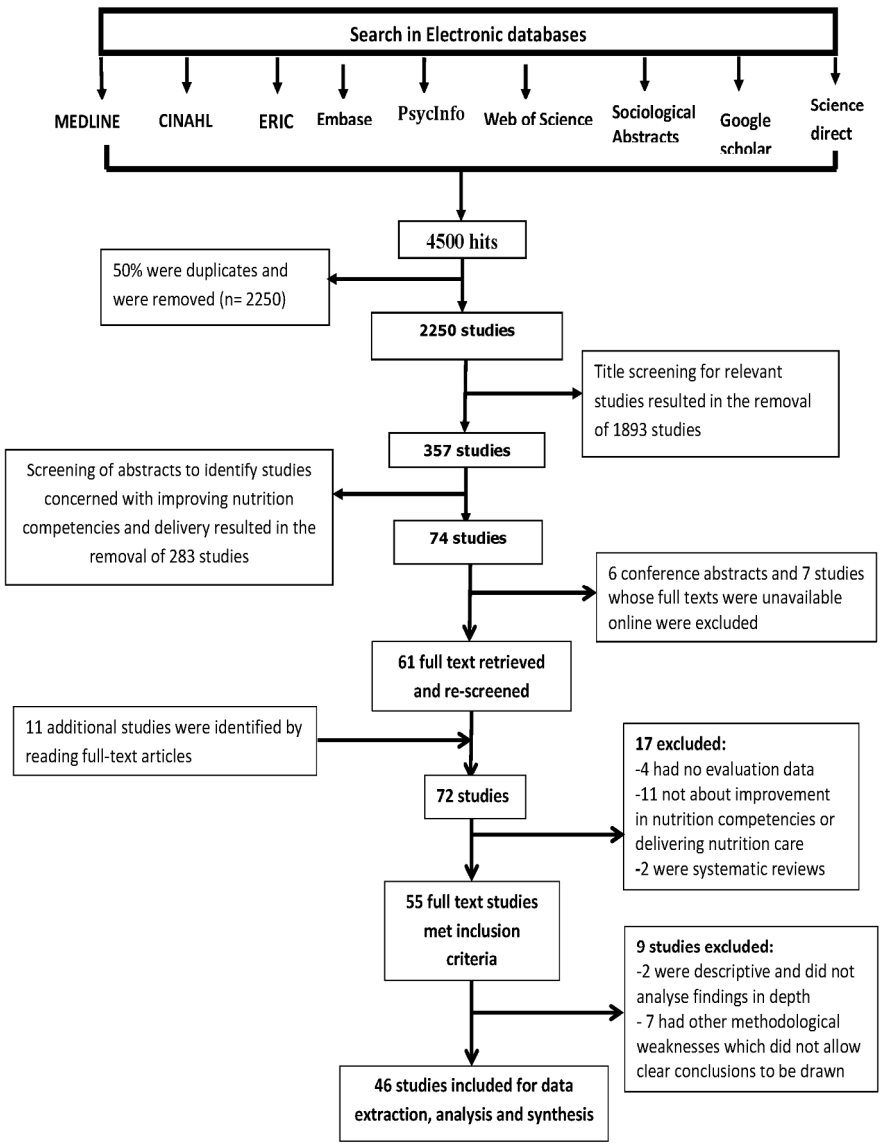


Figure 1: Flow chart of search and selection process

Figure 1: Search and selection process

173x233mm (300 x 300 DPI)

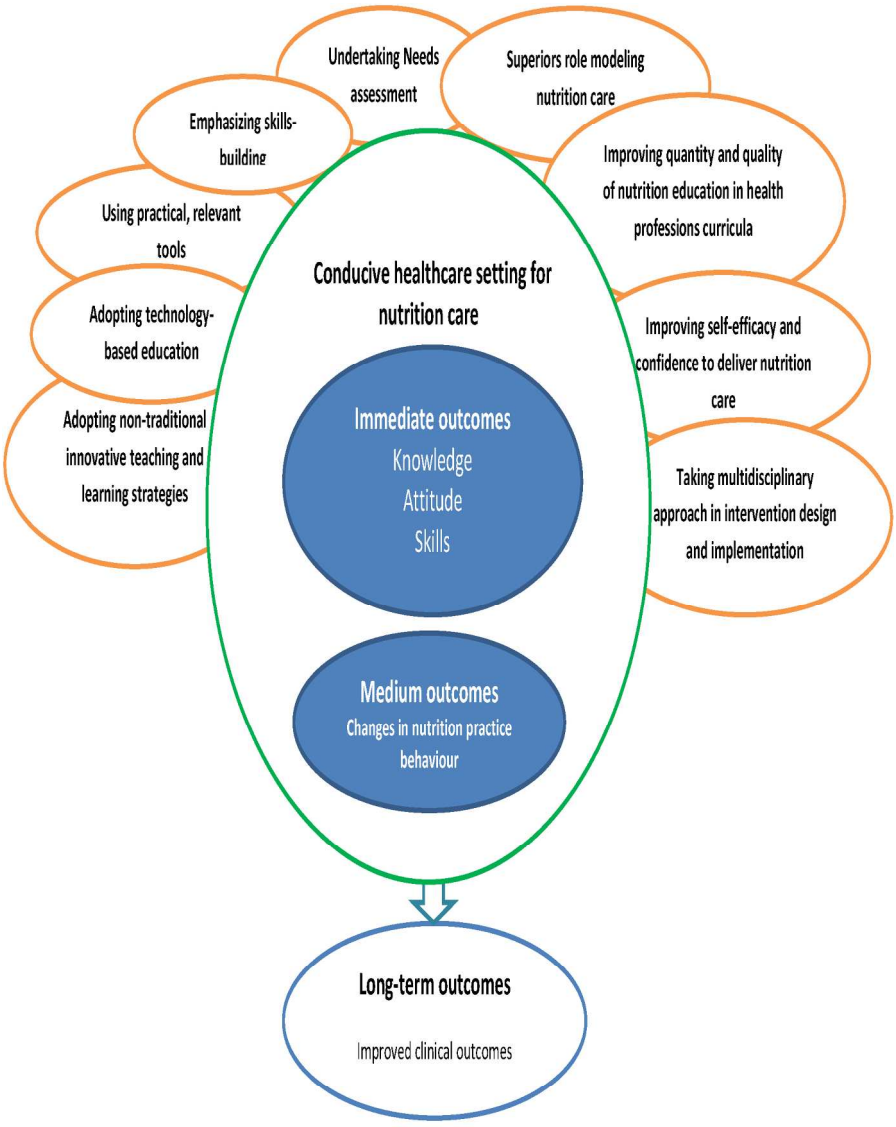


Figure 2: Revised theoretical model or programme theory

Figure 2: Theoretical model or revised programme theory

173x233mm (300 x 300 DPI)

BMJ Open

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2015-010084.R2
Article Type:	Research
Date Submitted by the Author:	28-Apr-2016
Complete List of Authors:	Mogre, Victor; UNIVERSITY FOR DEVELOPMENT STUDIES, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences Scherpbier, Albert; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Stevens, Fred; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Aryee, Paul ; University for Development Studies,, Department of Community Nutrition, School of Allied Health Sciences Cherry, Mary; University of Liverpool, Department of Health Services Research, Institute of Psychology, Health and Society Dornan, Timothy; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism, Patient-centred medicine, Public health, Qualitative research, Research methods
Keywords:	EDUCATION & TRAINING (see Medical Education & Training), Public health < INFECTIOUS DISEASES, Nutrition < TROPICAL MEDICINE, Realist review; nutrition; educational interventions; doctors; healthcare professionals

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Victor Mogre*[1, 2], Albert J.J.A Scherpbier[2], Fred Stevens[2], Paul Aryee[3], Mary Gemma Cherry[4], & Tim Dornan[2]

[1]Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, School of Medicine and Health Sciences, University for Development Studies, Ghana

[2]School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[3]Department of Community Nutrition, School of Allied Health Sciences, University for Development Studies, Ghana

[4]Department of Health Services Research, Institute of Psychology, Health and Society, University of Liverpool, United Kingdom

*__Corresponding author:__ Victor Mogre, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, University for Development Studies, P. O. Box TL 1883, Tamale.
Email: vmogre@uds.edu.gh

Key words: Realist review; nutrition; educational interventions; doctors; healthcare professionals

Word count: 5429, four tables, and two figures

ABSTRACT

Objective: To determine what, how, for whom, why, and in what circumstances educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals work?

Design: Realist synthesis following a published protocol and reported following Realist and Meta-narrative Evidence Synthesis: Evolving Standards (RAMESES) guidelines. A multidisciplinary team searched Medline, CINAHL, ERIC, EMBASE, PsyINFO, Sociological Abstracts, Web of Science, Google Scholar, and Science Direct for published and unpublished (grey) literature. The team identified studies with varied designs; appraised their ability to answer the review question; identified relationships between contexts, mechanisms, and outcomes (CMOs); and entered them into a spreadsheet configured for the purpose. The final synthesis identified commonalities across CMO configurations.

Results: Over half of the 46 studies from which we extracted data originated from the US. Interventions that improved the delivery of nutrition care improved skills and attitudes rather than just knowledge; provided opportunities for superiors to model nutrition care; removed barriers to nutrition care in health systems; provided participants with local, practically relevant tools and messages; and incorporated non-traditional, innovative teaching strategies. Operating in contexts where student and qualified healthcare professionals provided nutrition care in both developed and developing countries, these interventions yielded health outcomes by triggering a range of mechanisms, which included: feeling competent; feeling confident and comfortable; having greater self-efficacy; being less inhibited by barriers in healthcare systems; and feeling that nutrition care was accepted and recognised.

Conclusion: These findings show how important it is to move education for nutrition care beyond the simple acquisition of knowledge. They show how educational interventions embedded within systems of healthcare can improve patients' health by helping health students and professionals to appreciate the importance of delivering nutrition care and feel competent to deliver it.

STRENGTHS AND LIMITATIONS OF THIS STUDY

1. Application of the principles of realist synthesis to nutrition and education research is novel.
2. The characteristics and conditions of educational interventions that can improve the delivery of nutrition care, identified by this review, are important to the work of policy makers, researchers, health professions educators, and course developers.
3. Few reports of failed educational interventions were found, indicating a risk of positive publication bias.
4. Until our conceptual model is tested and refined in the real world, we consider it to be an indefinite candidate theory, presenting elements worth considering by those concerned with the design, implementation and evaluation of educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals.
5. We cannot assume that the research evidence we identified represents 'real world' practices, and therefore our claims for the transferability of this research must be guarded.

PROTOCOL

Published at http://www.systematicreviewsjournal.com/content/pdf/2046-4053-3-148.pdf

INTRODUCTION

Nutrition is an important component of healthcare. It plays a critical role in the prevention and treatment of most cardiovascular and cerebrovascular diseases, which are leading causes of morbidity and mortality throughout the world [1-3]. Nutrition is even more important in sub-Saharan Africa because malnutrition is a major cause of morbidity and mortality, particularly among children [4].

Several landmark reports [5 6] have identified the delivery of nutrition care as one of the core responsibilities of doctors. Research has also shown that nutrition counselling delivered by them has positive influence on patients' clinical outcomes. They and other healthcare professionals whose primary role is not nutrition care, however, often miss opportunities to advise patients on diet and health [7 8]. Health workers in primary care settings are particularly important providers of nutrition care because they can motivate even healthy individuals to adopt healthier lifestyles [9]. The care expected from primary care health workers includes nutrition assessment, education and counselling interventions, monitoring, and evaluation. Lack of knowledge [10], skills, and confidence [11 12] as well as negative attitudes towards delivery of nutrition care and low outcome expectancy [13], are barriers to healthcare professionals providing nutrition care. In addition to these individual-related factors, several system-related factors such as lack of time, office space, payment, materials, and education [14] also prevent the delivery of nutrition care by these healthcare professionals.

Many educational interventions have been designed and implemented to improve nutrition care but their effects have been inconsistent and often weak [15-17]. There remains a need, therefore, for interventions that can change healthcare professionals' behaviour in practice [15-17]. It is imperative to identifty contextual factors, which mediate or inhibit their competence and delivery of nutrition care [18 19]. In order to meet those needs, researchers have to identify components of effective educational interventions and processes.

To date, only one secondary research investigation has synthesised conclusions from existing evidence about nutrition care [20]. The authors of that review concluded that in-service nutrition training improved healthcare professionals' knowledge, nutrition-related counselling skills, and malnutrition management skills. The main limitation was that this was a traditional systematic review, which only considered in-service nutrition training programs. Its authors found that the evidence-base was very heterogeneous; studies had widely varying study designs with heterogeneous outcome measures, and there were wide differences in the competence, experience, and backgrounds of participating healthcare professionals. As the authors acknowledged, systematic review methodology limited their ability to recognize and account for the complexity of interactions within such interventions.

We reasoned that we could move the field forward by conceptualizing nutrition education interventions as complex ones within a realist research approach. As noted in our published review protocol [21], we recognised that educational interventions involve multiple actors operating at different levels with a range of artefacts in varied material environments [22]. We assumed that these components operate in non-linear ways to yield context-dependent outcomes. Realist synthesis explores 'what is it about this intervention that works, for whom and in what circumstances?' and is therefore an appropriate way to study complex interventions [23]. It is an iterative, theory-driven approach, which aims to unpack the theories that inform decisions and actions adopted in the design and implementation of interventions [24]. Realist synthesis begins with the development of an initial programme (or candidate) theory about how interventions work, the contexts in which they do and do not work, and the differentiated patterns of outcomes that they generate [25]. As the review progresses, researchers test the initial programme theory and refine it as more evidence becomes available [26].

Thus, the aim of this realist review was to determine what, how, for whom, why, and in what circumstances educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals work?

METHODS

VM is a nutritionist working in sub-Saharan Africa, which provided a context for the research. Other members of the team included scholars of medical education, evidence synthesis, social science, nutrition, and an experienced clinician.

Alteration from protocol

The review question above is broader than in the published protocol [21] because the search showed important findings from research in health professions other than medicine, which the team felt could make a valuable contribution.

Search methods

Search terms pertaining to nutrition, care, healthcare professionals, training etc. were scoped on two electronic databases. Resulting articles were reviewed and refinement of search terms was not considered necessary. Further explanation and a full list of the search terms can be found in our published protocol [21]; search strategies for individual databases are available from the first author upon request. The final search was undertaken on nine databases (Medline, CINAHL, ERIC, EMBASE, PsycINFO, Sociological Abstracts, Web of Science, Science Direct and Google Scholar), the latter of which was used to search for grey literature. Email alerts were set for journals and RSS feeds for databases to ensure that we identified new papers as soon as they became available.

Inclusion criteria

- **Study participants:** Medical students, students of other health professions, and practising healthcare professionals (e.g. nurses, physician assistant, etc).
- **Focus of intervention:** Developing participants' competencies in any aspect of nutrition practice behaviour.
- **Study design:** All.
- **Context of intervention:** Medical schools, residency and fellowship programmes, and interventions at both community and hospital settings
- **Publication language:** English.
- **Publication date:** January 1994 to December 2014 inclusive. This date range was chosen because preliminary searches indicated that educational interventions to improve nutrition care competencies and delivery among doctors and other healthcare professionals gained prominence within published literature around 1994.

Exclusion criteria

We sought to understanding generalists' delivery of nutrition education, and therefore we excluded research that only considered the education of dietitians and/or nutritionists since nutrition is their main responsibility. Whilst we excluded conference proceedings, opinion pieces, case studies, and abstracts, we used them to develop the initial candidate theories reported in our protocol [21]. We also excluded systematic reviews, although they informed the design of our data extraction form and provided an insight into context, mechanism, outcome (CMO) configurations and additional references. Papers were also excluded if they lacked evaluation or outcome data and not being about improvement in nutrition care competencies.

Study selection

Figure 1 shows the flow chart of the search and selection processes.The final search yielded 4500 hits. VM and TD initially screened the titles of 100 hits independently and compared their findings. There was almost complete agreement and VM continued with the screening. After eliminating duplicates, 357 studies were selected. Having obtained their abstracts, VM, TD, and MGC determined independently whether each study was concerned with improving nutrition care competencies and delivery of nutrition care. At a face-to-face discussion, we compared our choices, for which the kappa statistic of agreement was 0.9. This yielded 74 studies, six of which were excluded because they were conference abstracts. Seven studies could not be obtained despite repeated attempts. VM read the reference lists of the remainining 61 studies and all identified systematic reviews, identifying 11 more studies.

=Insert figure 1=

Quality assessment

It is regarded as acceptable in realist synthesis to include part(s) or whole studies for analysis and synthesis, provided the methods employed for collecting such data are robust [27]. As recommended by Pawson [25], the appraisal of primary studies was informed by their relevance as well as their rigour [25]. Our judgements of a study's relevance was informed by the extent to which the whole study or parts of it was relevant to our published initial program theory [21]. Our assessment of rigour was informed by the trustworthiness of studies' design, sample size, and data collection tools in relation to the outcomes reported. The Mixed Methods Appraisal Tool [28] helped us assess rigour[28]. Based on the exclusion and inclusion criteria, VM selected 55 of the 72 studies for quality assessment. Quality assessment was conducted by AS, TD, FS and MGC. This process resulted in the exclusion of nine studies from which clear conclusions could not be drawn because of methodological weaknesses. The remaining 46 studies were included into our data analysis. We kept notes of our reasons for including or excluding each study and resolved doubts about our judgements of study quality by discussing between ourselves. The processes of quality assessment and data extraction proceeded concurrently.

Data extraction, analysis and synthesis

For the purposes of data extraction, we followed guidance from previous related systematic reviews [20 22 29-31] and iteratively refined our procedures in accordance with the focus of the review. VM initially extracted data from a sample of 10 studies, discussed the findings with the other members of the team and used those discussions to guide further data extraction. Data extracted included:

- Study design, sample size, outcome data
- Educational levels of study participants (students vs. practising health workers)
- How course material had been developed
- Topics covered
- Methods of teaching and learning
- Methods of evaluating outcomes including data collection tools
- Intervention type (e.g. workshops, curriculum designs)
- Durations of intervention
- Contexts of intervention (e.g. practising healthcare professionals, students)
- Mechanisms generated
- Learning outcomes
- Impacts (if any) of intervention on clinical outcomes
- Any theories or mechanisms postulated by author(s) explaining the effects of interventions

We read all 46 included studies twice, transferring relevant data into our data extraction form. We identified the CMOs and interactions between them for each study as well as the theory informing each intervention. To do that, we assumed that the design of each study was informed by a theory, which the authors stated explicitly or implicitly. Identifying those theories helped us understand how interventions worked to generate outcomes. We discussed and reflected on all the data we had identified for each study, sometimes using extracts of publication narratives to foster reflection.

The next stage was to identify themes that were common to different studies. Using an interpretative and narrative approach, we discussed and synthesised initial conclusions, which we used to refute or refine the candidate theories in our published protocol [21]. We chose this process of synthesis in preference to a metaanalysis, which would not have been possible given the diversity in study populations, designs, interventions, and outcomes [32].

RESULTS

General characteristics of the studies

Table 1 provides a summary of the 46 studies. Twenty-seven (59%) came from the USA; seven (19%) from Europe; four each from South America (all from Brazil) and Asia; two from Canada and one each from Africa (i.e. South Africa) and Australia. In total, 4816 participants participated in them (median = 76 participants; interquartile range: 47, 178). Interventions that had healthcare professionals as participants had somewhat larger numbers (median = 98; interquartile range: 46, 163) than those having students as participants (median = 54 participants; interquartile range: 32, 152).

The studies had varied study designs (shown in table 2) with a preponderance (n=39, 85%) of quasi-experimental designs. Twenty-one studies had follow-up evaluations after the pre-test and post-test evaluations. The time period between post-test and follow-up evaluations ranged between 2 weeks and 12 months.

Most studies (n=32, 70%) evaluated outcomes using surveys of knowledge, attitudes, self-reported practice behaviours, self-efficacy, confidence, and feedback. A large proportion of these surveys were developed by the authors, who did not usually report the psychometric properties of their instruments. All the interventions that set out to improve knowledge used multiple choice questions (ranging between 1 and 78 questions). Changes in attitude before and after interventions were assessed using Likert scales, anchored with statements describing attitudes.

Most questionnaires measuring behaviour changes used self-reported changes in nutrition practice behaviour. A few studies observed clinical behaviour to measure changes in nutrition practice. For example, one study in the Netherlands [33] used incognito standardized patients to assess the impact of an intervention on the nutrition practice behaviour of GP residents. Another study in Brazil [34] measured nutrition indices (i.e.wasting, stunting, and underweight) of children to determine the impact of an educational intervention that aimed to improve the provision of nutrition counselling to mothers and/or care givers by doctors.

Table 1: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Levy *et al* [35]	Workshop	US	Primary healthcare professionals (doctors, nurses, physician assistants)	Pre-and post-test without control group	Training programme to provide information, tools, and technical assistance to primary care practices to improve delivery of preventive services and the management of chronic diseases	• Training well received by all participants • Self-reported improvement in knowledge between pre-and post-test • Self-reported satisfaction with intervention
Carson [36]	Part of an ambulatory Clerkship	US	4th year medical students	Cross-sectional	• Training medical students on assessment of body composition using tape measure • Facilitating the identification and treatment of metabolic syndrome	• Increased self-reported knowledge • Probable changes in practice behaviour
Taren *et al* [37]	Required course	US	Preclinical medical students	Pre-and post-test with control group	• Evaluation of an integrated nutrition education program • Nutrition intervention for disease prevention and therapy	• Significant increase in nutrition OSCE scores between pre-and post-test • Increased self-reported satisfaction in nutrition content of the curriculum
Buckley [38]	Varied formats (web-based, web-enhanced and traditional lectures)	US	4th year nursing students	Cross-sectional	Evaluating the effect of various formats of training on the nutrition knowledge of participants	• No significant changes in knowledge between the three formats • More positive perception of web-enhanced than the web-based and traditional

OSCE = Objectively Structured Clinical Examination

Table 1 Continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ray *et al* [39]	Lectures, demonstrat-ions, and interactive practical sessions	UK	3rd and 4th year clinical students	Pre-and post-test without control group	• Evaluating the effectiveness of a nutrition education intervention in a cohort of tomorrow's doctors using knowledge, attitude and practice scores related to clinical nutrition • Covering topics relating to hospital malnutrition	• Significant improvement in knowledge scores between pre- and post-test • Significant changes in attitude scores • Students reported satisfaction with the course • Applied acquired knowledge to patients
Ke *et al* [40]	Workshop	Taiwan	Nurses in ICU, GI and GS	RCT	• The effects of educational intervention on nurses' knowledge, attitudes and behavioural intentions regarding supplying artificial nutrition and hydration • Coverage of topics such as normal nutrient metabolism, nutrient metabolism for terminal cancer patients, and appropriateness of supplying ANH to terminal cancer patients	• Significant improvement in knowledge between pre and post-test • Significant changes in mean attitude scores • Significant changes in behaviour intentions
Buchowski *et al* [41]	A computer-based and a required course	US	First year medical students	Pre-and post-test without control group	• The efficacy of 2 modules (Nutrition Anaemias and Diabetes and Weight Management) used by first year medical students • Coverage of topics such as nutritional anaemias, diabetes, and weight management	• Increase in knowledge scores between pre- and post-test • Developed positive attitudes towards nutrition after intervention • Mixed results with regard to confidence to counsel patients on nutrition

RCT = Ransomized Controlled Trials; ICU = Intensive Care Unit; GI= Gastroenterology; GS= General Surgery; ANH =Artificial Nutrition and Hydration

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Puoane *et al* [42]	Workshop	South Africa	Nurses	Pre-and post-test without control group	• Assessing the attitudes and perceptions towards severely malnourished children and their mothers/caregivers pre-and post-intervention • Coverage of topics such as principles of care set out by the WHO for managing severe malnutrition	• Positive change in attitudes towards malnourished children after intervention • Change in perceptions about malnourished children after training • Reduction in case fatalities
Hillenbrand and Larsen [43]	Workshop	US	Paediatric residents	Pre-and post-test without control group	The effect of an educational intervention on paediatric residents' knowledge about breastfeeding, their confidence in addressing lactation issues, and their management skills during clinical encounters with breastfeeding mothers.	• Intervention improved the knowledge of paediatric residents about breastfeeding • Confidence increased after the intervention • Limited changes in participants' practice behaviour after intervention
Maiburg [33]	Computer-based instruction	The Netherlands	GP trainees	Pre-and post-test with control group	• The impact of a computer-based instruction on nutrition knowledge and practice behaviour of GP trainees. • Covered a wide range of nutrition including food pyramid, obesity, diabetes mellitus, hypercholesterolemia, hypertension, irritable bowel syndrome	• Improvement in knowledge scores after intervention • Changes in practice behaviour

GP = General Practitioner; WHO = World Health Organisation

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ockene *et al* [44]	Workshop	US	Internists	RCT	• Impact of a training programme on physicians' lipid intervention knowledge, attitudes and skills • Improved skills on brief dietary risk assessment and patient-centred counselling	• No significant changes in self-reported knowledge scores • Limited changes in attitudes • Counselling scores increased between pre and post-test
Zaman *et al* [45]	Workshop	Pakistan	Healthcare workers	RCT	Impact of training health workers in nutrition counselling in enhancing their communication skills and performance, improving feeding practices, and reducing growth faltering in children aged 6-24 months.	• Improved communication skills • Improved consultation performance • Mothers able to recall recommendations of health workers
Eisenberg *et al* [46]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	Improving healthcare professionals nutrition behavior, personal habits and their perceived ability to advise overweight or obese patients through the inclusion of 'culinary education' in the form of cooking demonstrations and participatory hands-on cooking workshops, combined with more traditional didactic, nutrition-related presentations	• Self-reported significant positive changes in ability to counsel obese patients • Changes in participants' nutrition behaviours

RCT=Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Roche *et al* [47]	Computer-based instruction	US	Paediatric residents	RCT	A computer-based compact disc instructional program covering the nutrition topics of oral rehydration therapy, calcium, and vitamins.	• Modest improvement in self-reported knowledge scores after intervention • Positive attitudes towards computer instruction after intervention • Participants believed intervention enhanced their knowledge in nutrition
Gance-Cleveland [48]	Workshop	US	Nurse practitioners	Pre-and post-test without control group	• Four hour training session on Healthy Eating and Activity Together (HEAT) Clinical Practice Guideline (CPG) to improve provider behaviour and efficacy • Topics covered included obesity prevention, behaviour modifications and family counselling, family collaboration and advising	• Post training results revealed significant improvement in practitioner knowledge • Post training results revealed significant improvement in practitioners' intent to improve behaviour • Post training results revealed significant improvements in practitioners' report of increased confidence in ability to address barriers
Ray *et al* [49]	Workshop	UK	Junior doctors	Pre-and post-test without control group	Nutrition assessment in hospitalised patients	Significant improvement in knowledge, attitudes and practice scores

RCT=Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Bassichetto and Rea [50]	Workshop	Brazil	Paediatricians and nutritionists	RCT	• Training intervention to equip junior doctors to run a hospital nutrition awareness week to contribute to the improvement in nutrition care • Topics covered included clinical and public health nutrition, organisational management and leadership strategies	• Significant improvement in knowledge scores after intervention • Improvement in dietary counselling after intervention
Dacey *et al* [51]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	• The impact of two types of live-face-to-face CME programs aiming to alter participants' thinking and behaviour and comfort with the use of lifestyle medicine • Topics included the history and rationale for lifestyle medicine, exercise medicine initiative, and lifestyle medicine competencies	• Improvement in the perception of barriers to lifestyle medicine • Improvement in self-reported knowledge • Increased confidence to counsel
Ritenbaugh *et al* [52]	4-year integrated nutrition curriculum	US	All levels of medical students	Cross-sectional	Evaluation of an integrated nutrition curriculum	• Changes in knowledge • Students satisfied with curriculum

RCT = Randomized Controlled Trial; CME = Continous Medical Education

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Tziraki and Graubard [14]	Workshop	US	Primary care doctors	RCT	• Training to improve the adoption of a manual to guide primary care practices in structuring their office environment and routine visits to improve nutrition screening, advice/referral, and follow-up for cancer prevention • Compared the effect of training on the manual with mailing the manual to practices	• Greater adoption of manual recommend-ations among practices in the training group • Training group adhered closer to diet screening recommendations in the manual • Changes in office environment were conducive to nutrition screening and dietary advice
Edwards and Wyles [53]	Workshop	UK	Healthcare professionals	Pre-and post-test without control group	Effectiveness of training sessions for health professionals concerning folic acid in pregnancy	• Improvement in knowledge after training • Participants enjoyed most parts of the training
Castro *et al* [54]	Workshop	Brazil	Doctors in the ICU	Pre-and post-test with control group	A multifaceted nutritional educational intervention on the quality of nutritional therapy and clinical outcomes of critically ill patients	• Significant improvement in participants' knowledge after the intervention • Reduction in patients' length of stay of in the ICU • Adequacy of nutritional therapy improved significantly • Initiating enteral nutrition earlier than 48 hours more commonly

RCT = Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pelto *et al* [34]	Workshop	Brazil	Doctors	RCT	• Training to improve the nutrition counselling behaviour of physicians and caregiver retention of nutrition advice using the nutrition component of the WHO/UNICEF strategy of Integrated Management of Childhood Illness (IMCI) • Reducing growth faltering in children by means of the nutrition training program	• Modest changes in physician behaviour in practice • Mother's uptake of physician advice improved • Reduction in malnutrition cases
Kohlmeier *et al* [55]	Computer-based instruction	US	First year medical students	Pre- and post-test without control group	Evaluating students' attitudes and self-efficacy in nutrition and cancer and acceptability of a computer-based instruction	• Significant improvement in attitudes and self-efficacy after intervention • Students generally accepted computer-based instruction
Bjerrum [56]	Workshop	Denmark	Nurses	Pre-and post-test without control group	• Improving nurses knowledge in nutrition and their attitudes towards their responsibility to providing nutrition care in relation to assessment and management • Coverage of basic nutrition education, malnutrition in the hospital setting	• Changes in knowledge and attitudes • Participants felt more secure in their ability to provide nutrition care • Participants were satisfied with the intervention

RCT = Randomized Controlled Trials; WHO = World Health Organisation; UNICEF = United Nations Children's Fund

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pedersen *et al* [57]	Workshop	Denmark	Nurses	Pre-and post-test without control group	Training programme to implement nutritional guidelines to change nurses' nutrition practice behaviour relating to the identification of patients' eating habits, improving patients' knowledge about appropriate food choices and number of snacks eaten between meals to risk of undernutrition in hospitalized patients.	• Modest changes in nutrition practice behaviour • Improvement in the eating difficulties of patients • Patients' knowledge of appropriate food choices improved
Conroy *et al* [58]	Required course	US	2nd year medical students	Pre-and post-test without control group	Impact of an innovative Preventive Medicine and Nutrition curriculum on students' confidence about addressing patients' diet and exercise patterns and on their own health habits	• Personal dietary, exercise patterns of participants improved • Confidence in their ability to address diet and exercise in patients increased
Endevelt, Shahar & Henkin [59]	Workshop	Israel	2nd year medical students	Cross-sectional	• Identification of time slots for nutrition training for medical students • Impact of a nutrition education programme on students' knowledge • Topics covered included nutrition and dietary recommendations for healthy people. Health risks of obesity	• Changes in knowledge • Students considered nutrition curriculum to be effective

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Olivarius *et al* [60]	Seminar	US	Primary care doctors	Pre-and post-test with control group	• Improving the quality of diet recording and instruction in primary care • Diet counselling for diabetes patients using one's own diet	• Improvement in personal dietary behaviours of participants • Changes in attitudes towards dietary counselling
Schlair *et al* [61]	Workshop	US	First year medical students	Pre-and post-test without control group	• The feasibility and impact of a brief nutrition-counselling curriculum on medical students' nutrition knowledge, confidence, attitudes and practices and their own affect the students' own nutrition behaviour and attitudes • Topics covered were nutrition-related counselling confidence for patients with obesity and chronic disease and understanding of simple nutrition messages	• Significant changes in self-efficacy scores • Significant changes in attitudes • Improvement in nutrition counselling competence • Improvement in personal dietary habits
Scolapio *et al* [62]	Workshop	US	Doctors, dieticians and pharmacist	Pre and post-test with control group	• Impact of a live continuing medical education nutrition course on participants' nutrition knowledge and practice behaviour. • Coverage of a variety of topics including identifying methods to feed patients with acute pancreatitis, parenteral nutrition, management of obesity, and others.	• Significant changes in knowledge • Confidence in counselling patients on nutrition improved • Modest changes in practice behaviours

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Kennelly *et al* [63]	Workshop	Ireland	GPs and nurses	Pre-and post-test without control group	The impact of a dietetics intervention on healthcare professionals' knowledge in nutrition and practice behaviour related to the management of malnutrition in hospitalized patients and the acceptability of the educational intervention	• Significant changes in knowledge • Modest changes in practice behaviours • Level of acceptance for the intervention increased
Lewis *et al* [64]	Internet-based instruction	US	Paediatric residents	Cross-sectional	• Evaluating paediatric trainees' engagement, knowledge acquisition and satisfaction with nutrition modules delivered in interactive and non-interactive format • Coverage of breastfeeding practices	• Significant change in knowledge • Engagement with course content increased • Level of satisfaction with intervention increased
Acuna *et al* [65]	Workshop	Brazil	Medical and nursing students	Pre-and post-test without control group	• Evaluating the effect of an intensive education course given to health care professionals and students • Topics covered related to hospital malnutrition	Ability to diagnose malnutrition improved
Powell-Tuck *et al* [66]	Required course	US	2nd year medical students	Pre-and post-test without control group	Development and inception of a 7-day curriculum on diet and health	• Students' feedback was positive • Significant changes in knowledge

GPs = General Practitioners

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Afaghi *et al* [67]	Workshop	Iran	Clinical year 4 and 5 students	Pre-and post-test without control group	• Clinical based case study teaching to enhance clinical skills regarding the role of nutrition in chronic disease • Topics covered included the role of nutrition in chronic diseases, assessment of dietary intake and weight management	• Student perceptions of the adequacy of the instruction were positive • Significant changes in knowledge
Carson *et al* [68]	Required course	US	4th year medical students	Pre-post-test with control group	The outcomes of an integrated cardiovascular nutrition in the fourth year of medical school at the University of Texas	• Significant changes in knowledge • Significant changes in attitude • Self-efficacy in addressing nutrition issues improved
Vanderpool *et al* [69]	Continuous medical education	US	Paediatric gastroenterology residents and paediatric gastroenterologists	Pre-and post-test without control group	• Improving nutrition knowledge acquisition and dissemination. • Topics covered included paediatric nutrition and paediatric nutrition assessment	• Changes in knowledge • Changes in behavior • Changes in patient outcomes
Duerksen [70]	Clinical rotation	Canada	Second year medical students	Pre-and post-test without control group	Assessment of hospitalized patients' nutrition using the Subjective Global Assessment (SGA).	• Students correctly identified malnourished patients • Increased confidence in nutritional assessment
Engel *et al* [71]	Computer-based training as part of family practice clerkship rotation	US	Third year medical students	Pre-and post-test without control group	Knowledge and self-efficacy in prescribing diets for patients with diabetes	• Improved changes in knowledge • Improved changes in self-efficacy

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Richards & Mitchell [72]	Presentation by a dietitian to individual participants	Australia	GPs	Pre-and post-test without control group	Presentation of a nutrition manual and behaviour modification strategies	• Improved confidence to provide specific nutrition information and dietary recommendations • Increase in the use of the nutrition manual • Nutrition counselling of patients improved
Kipp [73]	Computer-based instruction	US	First year medical students	Pre-and post-test without control group	Evaluation of a CAI module on food Guide Pyramid and dietary guidelines	• Students considered CAI as appropriate learning tool for nutrition concepts • Students satisfied with format • Changes in knowledge
Cooksey *et al* [74]	Computer-based instruction	US	Pre-clinical medical students	Cross-sectional	Evaluation of series of interactive, multimedia educational programs (Nutrition in Medicine) that teach the basic principles of nutritional science and application to cases	Advantages of accessibility, self-paced study, interactivity, immediate feedback, and tracking students' performance were noted
Cheatham *et al* [75]	Computer-based tutorial	US	Nursing, physician assistant and physical therapy students	Pre-and post-test without control group	Development and use of a computer-based tutorial on nutritional assessment	• Significant changes in knowledge scores • Students felt amount of content was adequate
Kolasa *et al* [76]	Workshop	US	Dietetic students, family medicine residents and third year medical students	Cross-sectional	Encouraging effective communication with both media and consumer through article preparation	Participants found the intervention to be an interesting way to learn about current food and nutrition issues
Fox [77]	Required course	Canada	Community nutrition graduate students	Pre-and post-test without control group	Incorporation of arts as strategies for understanding and addressing community health issues.	Students recognised the incorporation of arts as a mechanism of conducting health research, advocacy, education, healing, and capacity-building initiatives

GPs=General Practitioners; Computer-Assisted Instruction

Intervention focus, types, teaching and learning formats, duration of interventions and expected learning outcomes

Only 11 studies (24%) explicitly stated the theoretical underpinning of their interventions. These included experiential, social, and cognitive learning theories as well as cognitive theory of multimedia learning. The purpose of most interventions was to improve participants' competencies (i.e. knowledge, skills and attitudes) in a variety of nutrition topics (shown in table 1). Studies originating from developing countries tended to cover topics related to infant and young child feeding practices, whereas those from developed countries covered topics relating to hospital malnutrition and nutritional management of chronic diseases. Most studies in which students participated aimed to increase curriculum contact hours and nutrition content. Studies involving practitioners were usually CME programs aiming to improve knowledge, attitudes, skills, and practice behaviour in specific topics such as breastfeeding practices and dietary counselling. Teaching and learning formats included lectures, problem-based learning tutorials, nutrition slogans, demonstrations, role plays, group discussions, games, and video presentations. All interventions used more than one teaching and learning format except six, which were either lecture-based or computer-based only [33 40 47 55 64 69]. Almost all the interventions used innovative teaching and learning methods. Interventions involving students were usually obligatory and lasted from between two weeks to four years. Those involving professionals were generally shorter. The shortest intervention was a one-hour intensive session for general practitioners and other healthcare professionals on the benefits of giving folic acid to women of childbearing age [53]; the longest were two four-year integrated nutrition curricula for medical students [37 52]. Inconsistent reporting of the length of interventions (including use of terms like credit hours) made it difficult to determine their average lengths.

Table 2: Study designs and data collection methods

Characteristic	Frequency (%)
Study design	
Randomised control trials	7(15%)
Quasi-experimental	
Pre-test-post-test with control group	6(13%)
Pre-test-post-test without control group	26(57%)
Cross-sectional	7(15%)
Methodological approach	
Qualitative	5(10%)
Quantitative	32(70%)
Both qualitative and quantitative	9(20%)
Data collection method	
Questionnaires/surveys only	32(70%)
Observations only	2(4%)
Focus group discussions only	2(4%)
Questionnaires/survey with other methods (e.g. interviews, observations)	10(22%)
Format of intervention	
Training programs	12(26%)
Workshops	9(20%)
Required courses	7(15%)
Technology-based (computer-based, internet-based)	11(24%)
Ambulatory clinical rotations	2(4%)
Seminars	1(2%)
Continuing medical education programs	4(9%)
Healthcare professionals (n=22, 48%)	
Doctors (general practitioners/primary care)	8(36%)
Nurses	5(23%)
Multidisciplinary participants (e.g. nurses, doctors, pharmacists)	9(41%)
Students (n=24, 52%)	
Undergraduate, preclinical	14(58%)
Undergraduate, clinical	5(21%)
Postgraduate	5(21%)

Context-Mechanisms-Outcomes Configurations

Table 3 lists the CMOs identified from the included studies. We describe here how those interacted to yield CMO configurations.

Emphasizing skills development instead of knowledge outcomes ("Let me be skilful")

Researchers were often triggered to design interventions by professionals' lack of knowledge about nutrition. This was particularly true of undergraduate education [38 41 59 64 66 67], where all but one [53] of the interventions primarily targeting knowledge took place. Yet interventions that only aimed to improve knowledge were less likely to change practice behaviour. In four studies, for example, significant gains in knowledge did not predict practice scores [39], improve students' assessment of the nutrition status of overweight patients [36], influence behaviour change intentions [40], or affect dietary counselling for mothers/caregivers of children aged 12-24 months [50]. Furthermore, there were interventions, which did not significantly increase knowledge yet changed behaviour. For example, a significant improvement in diet counselling during audiotaped physician-patient interactions [44 51] and increased self-reported counselling behaviour and confidence [51] took place without any significant increase in knowledge. In one study, Ockene et al [44] noted that 'a large proportion (1.5 hour) of the entire 3-hour CME training program was devoted to the learning of counselling and dietary assessment skills'. These findings show that it is important to train skills and create learning environments that encourage the acquisition of skills in order to change healthcare professionals' nutrition care behaviour [78 79].

Table 3: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Participants lacking nutrition counselling skills • Participants having inadequate knowledge • Participants being future and practising healthcare professionals	Emphasizing skills building instead of knowledge outcomes ("let me be skillful")	• Being more confident • Feeling adequately prepared	• Use of dietary counselling steps • Self-reported confidence to counsel patients and change in counselling behaviour
• Lack of faculty to provide nutrition training at both preclinical and clinical settings • Participants being future and practising healthcare professionals	Superiors role modelling the delivery of nutrition care ("I look up to you")	• Being more confident • Sense of acceptance • Sense of credibility • Anticipation of being valued	• Better delivery of nutrition care in clinical settings • Greater confidence in nutrition counselling
Participants being future and practising healthcare professionals	Meeting the needs of potential participants of an intervention ("Ask me what I want")	• Interest • Sense of knowing the needs of participants	• Greater satisfaction with educational intervention • Signicant gains in knowledge outcomes
• Participants lacking time to provide nutrition care • Lack of payment for providing preventive care • Participants having limited access to referral sources and materials for nutrition care • Poor investment into nutrition care • Lack of supportive office systems to deliver nutrition care • Separation of prevention and curative services in the health care system	Addressing structural and systemic factors to make an enabling environment ("Is my consulting room enabling?")	• Feeling comfortable to deliver nutrition care • Sense of acceptance • Perceiving fewer barriers to the delivery of nutrition care • Sense of recognition	• Structured office environment conducive to providing nutrition-related services • Strategies to address lack of support systems • Encountering fewer barriers to lifestyle medicine

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Inadequate instruction and syllabi for nutrition training in curricula • Busy healthcare professionals lacking time to attend continuing education programs in nutrition	Incorporating technology-based education ("My computer is a learning tool")	• Convenience and self-paced study • Interactivity • Instant feedback • Accessibility	• Significant gains of knowledge • More positive attitudes towards nutrition care • Changed real-time practice behaviour • Greater confidence in skills of nutrition counselling • Better counselling skills
• Practising health care professionals • Participants lacking appropriate tools to deliver nutrition care • Participants' personal dietary and lifestyle habits • Participants having inadequate training in nutrition • Participants not routinely addressing patients' nutrition problems • Existence of structural barriers to providing nutrition care to patients	Providing participants with local, practical relevant tools and messages ("Give me tools")	• Removal of perceived barriers • Feeling comfortable	• Facilitating the uptake of nutrition messages • Changed nutrition practice behaviour • Engaging in specific rather than general discussion with patients • Giving relevant advice and recommendations to patients • Simplifying complex messages
Poor interest in nutrition education	Use of non-traditional teaching strategies ("Using the right strategy for the right job")	• Capture interest of participants • Meet the learning needs of participants • Active participation and uptake of knowledge and skills • Relevance of learning	• Engaging the management of malnutrition • Engaging in exercise and dietary counselling • Ability to counsel overweight/obese patients • Significant changes in knowledge gains • Positive personal health habits of participants

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Lack of confidence to deliver nutrition care • Among both future and practising healthcare professionals	Improving self-efficacy ("I feel that I can do it, so I will do it")	• Feeling motivated • Feeling confident	• Self-reported changes in practice behaviours • Intentions to change behaviour
• Participants having inadequate knowledge • Among both future and practising healthcare professionals • Participants lacking training in diet counselling • Lack of patient motivation to change dietary pattern • Lack of time	Improving the personal health habits of healthcare professionals ("Do as I do")	• Being more confident • Sense of being a role model • Sense of relatedness to patients	• Greater counselling confidence • Intentions to change behaviour • Positive healthy lifestyles • Engaging in dietary assessment • More favourable attitudes towards nutrition counselling
• Low priority given to nutrition • Inadequate time dedicated to nutrition • Healthcare students • Reported inadequate knowledge in nutrition	Integrating nutrition content ("Add nutrition to my learning")	• Accepting nutrition education • Reduction in perception of time limitations	• Greater recognition of the relevance of nutrition education • Increased in the number hours dedicated to nutrition • Greater gains in cognitive outcomes
• Multidisciplinary nature of healthcare delivery • Cross-disciplinary nature of nutrition	Adopting a multidisciplinary approach in intervention design and implementation ("Working with others")	• Sense of belonging • Acceptance • Recognising the multidisciplinary nature of nutrition healthcare delivery	• Multi-disciplinary designed program • Meets the needs of all participants • Greater satisfaction

Superiors role modelling the delivery of nutrition care ("I look up to you")

A candidate theory in our published protocol [21], that healthcare professionals would be more likely to deliver nutrition care if they saw their superiors model the same behaviour, was apparent in the evidence. Seeing superiors model nutrition care led research participants to feel more confident, accepted, and credible. They anticipated their actions being valued, which led them towards changing their nutrition practice. Virtual physician mentors [41], simulation of GP consultations using video clips [33], physicians describing how they addressed nutrition in practice [68], and role modelling by physicians in classes [68] were among the interventions which provided positive role modelling.

Meeting the needs of potential participants of an intervention ("Ask me what I want")

Most interventions were modelled on the theory that education will be most successful when it is designed to meet participants' needs [35 36 39 49 51 53 59 62 63 67-69]. Needs assessment identified gaps in learners' knowledge or practice behaviour [62], and how they learned best. It informed the content, format, and design of curricula. It helped select teaching and learning methods to which participants were receptive, which they found interesting and satisfying, and which led them to value their education.

Addressing structural and systemic factors ("Is my consulting room enabling?")

As well as education, interventions that improved working environments influenced participants' behaviour and helped maintain changes that had been achieved [57]. Eight studies helped participants address lack of support [35 48 49 69] and systematic barriers [14 34 51 57]. They restructured office environments to make them more conducive to providing nutrition care [14]. Pelto et al [34], for example, stated that 'structural conditions in the public health system in Pelotas provided an environment in which physicians could utilize their knowledge'(p360). Other researchers provided nutritional messages that busy primary care providers could deliver to patients [35]. Presentations on change management and leadership [49] and provision of guidelines on office organization [14] helped improve nutrition care. Collaboration between education and care delivery leaders helped remove structural and systemic barriers [30]. These created working environments that were conducive to the delivery of nutrition care.

Incorporating technology-based education ("My computer is a learning tool")

Seven studies used technology to resolve challenges relating to healthcare professionals having insufficent time to attend continuing education programs, programs having inadequate nutrition content, and faculty being unavailable to teach [33 41 47 55 64 68 74]. Computer-based and internet-based interventions allowed easy updating of content [33], permitted self-directed and independent study of nutrition information [33 47], presented content consistently [68], were accessible [74], promoted interactivity [74], and were convenient for participants because they were self-administered [33 68] and self-paced [74]. These interventions led to significant gains of knowledge [41 47 55 64], positive attitudes [33 47], increase in self-assessed nutrition counselling skills [33 55], and real-time practice behaviour [33]. The convenience, interest, and independent nature of this type of education contributed to those outcomes.

Providing participants with local, practically relevant tools and messages ("Give me tools")

Some researchers theorised that making local, practically relevant tools and messages available in practice contexts would change the behaviour of trainee healthcare professionals. The tools they provided included memorable slogans [35], simple 'key take home messages' [35 39 42 63], personalized nutrition messages [35], and locally relevant examples [34]. Researchers simplified nutrition messages [35], provided resource materials and tools to resolve problems in counselling and

assessing patients [34 63], and adapted advice for local conditions [34]. Those interventions helped professionals engage in specific rather than generic discussions with patients, and provide advice and recommendations that patients found relevant [34]. The authors of an RCT, which improved physicians' counselling of mothers with malnourished children aged 12-24 months in Brazil [34], attributed children's improved nutritional status to this provision of locally appropriate messages and tools.

Using non-traditional teaching and learning strategies ("The right strategy for the right job")

Another theory, which guided interventions, was that non-traditional teaching and learning strategies would change professionals' behaviour. For instance, Hillenbrand *et al*. [43] hypothesized that providing a series of interactive educational interventions to paediatric residents would increase their knowledge about breastfeeding and lactation problems and increase their confidence to counsel breastfeeding women. Interventions, which sometimes complemented lectures, included discussions, simulated patient cases, group work, role plays, hands-on demonstrations, group practice, panel discussions and case-based learning. Other interventions included problem-based learning tutorials, computer or web-based cases, student-led debates, self-assessment exercises, and clinical case presentations [58 62 68]. These interventions provided practical experience and promoted active learning. They emphasised the development of skills rather than just knowledge. They engaged participants' interest and helped them assume responsibility for their own learning. These interventions caused significant changes in participants' knowledge, personal health habits, confidence to provide exercise and dietary counselling, ability to counsel obese patients, and ability to manage malnutrition. Carson *et al.* [68]attributed the enhanced nutrition counselling skills of students in a four week ambulatory care rotation to their innovative combination of teaching strategies.

Improving self-efficacy ("I feel that I can do it, so I will do it")

Self-efficacy is a basic tenet of Bandura's social learning theory [80]. This term describes individuals' confidence in their ability to perform a task or achieve an outcome. It is a key influence on behaviour [80]. Eight studies explicitly set out to improve participants' self-efficacy by increasing their confidence. They adopted strategies like role modelling by practising physicians[68], role playing using either simulated or real patients [43 44 48 58], providing demonstrations and hands on practice sessions [35 43 44 46 48 61 68], and viewing then discussing videos and web-based cases [44 68]. Four each of these interventions were conducted among future healthcare professionals and practising healthcare professionals. They were effective in both settings.

Improving the personal health habits of the healthcare professional ("Do as I do")

Four interventions, which stimulated practising [46 60] and health professions students [58 61] to take better care of their own health, had positive outcomes. These included regular consumption of fruits and vegetables, personal awareness of calorie consumption, engagement in regular physical activity, and development of culinary skills. In both settings, these led to better self-reported healthy lifestyles and self-reported ability to undertake dietary assessment [61], counselling confidence [46 58 61], self-assessed knowledge [60] and even treating a higher proportion of diabetic patients with diet alone [60]. Healthcare professionals, who considered themselves role models for patients, felt more confident to advise patients to do as they had done [46 58 61].

Initial and revised programme theory

Our published protocol [21] presented candidate theories, and a theoretical model, which we briefly repeat here. Drawing on social cognitive theory, we postulated that:

- Healthcare professionals' ability to deliver nutrition care is influenced by their competence, which is the outcome of a learning process, which is influenced by factors within academic environments. Those factors include the quantity and quality of nutrition content in curricula, the teaching and learning methods employed, and the extent to which learning is reinforced.
- Professionals are more likely to care for patients' nutrition if they have high self-efficacy for nutrition care and vice versa.
- Professionals' delivery of nutrition care is a behaviour demonstrated in the social context of workplaces, which is influenced by observing and modelling the behaviours, attitudes and emotional reactions of others (e.g. superiors) [81]. It is also influenced by the structural determinants of behaviours such as the workplace settings themselves (e.g. hospital/community, emergency/paediatric/general ward), job descriptions/role, time and availability of other staff to undertake particular roles.

The review process described above examined those theories, which led us to revise, add components to, and broaden our theoretical model (shown in figure 2). 'Outcomes', in realist terminology, can be short, medium and long-term [82]. We have added a hierarchy of outcomes to our theoretical model.

The items in the model are interrelated as opposed to operating in isolation from one another. They do not operate in a linear fashion. Several context-mechanism-outcome configurations could be generated from the data. For instance, needs assessments identifies knowledge, skills and attitude gaps and other educational needs of potential participants. The outcome of the needs assessments informs the design of the educational intervention as well as its characteristics. It informs what kind of characteristics, or strategies the intervention should adopt in order to realise the desired outcome. These strategies could include improving the personal health habits of healthcare professionals, adopting technology-based education, improving skills development, adopting innovative teaching and learning strategies, role modelling, and others. These generate mechanisms (not indicated in the diagram) such as interest, receptivity, and acceptance, which generate short-term outcomes such as improved knowledge, attitude, skills, self-efficacy, values and personal habits. The immediate and short-term outcomes may act as mechanisms to bring about change in nutrition practice behaviour (medium-term outcome). Doctors and other healthcare professionals may change their nutrition practice behaviour as a result of having adequate knowledge, skills, attitudes, confidence and self-efficacy. A change in nutrition practice behaviour will mean increased delivery of nutrition care to patients which may result in the long-term goal of improved clinical outcomes (long-term outcomes) of patients. However, these outcomes can best be enhanced and maintained if there is an enabling health care setting (context). This could be realised by enhancing certain conditions/contexts such as restructuring the healthcare system, removing structural and systemic barriers, adopting favourable policies for nutrition care, providing appropriate tools to deliver nutrition care, investing more in preventive care, and providing an office that makes it easier to provide nutrition care. Providing an enabling healthcare setting was central to all the CMO configurations identified.

=Insert figure 2=

We present in table 4 a summary of the characteristics of interventions in accordance with what works, for whom, and under what conditions.

Table 4: Overview of what works, for whom, under what circumstances, to achieve what?

What works	Choosing interventions, which are educationally and clinically relevant to the needs of participants Adopting appropriate teaching and learning techniques Building on self-efficacy and confidence through role modelling Emphasizing skills development rather than pure knowledge gains Improving the personal lifestyle habits of healthcare professionals Removing systemic barriers and restructuring healthcare systems to make healthcare settings more enabling Using practical, relevant tools Using Information and Communications Technology (computer-based education)
For whom	Doctors and other practising healthcare professionals Students of the health professions
Under what circumstances	Within a multidisciplinary approach to nutrition education and care Supported by both educational and care delivery leaders Where nutrition care is recognized as an important component of: Care delivery systems Curricula Where healthcare systems are structured to be conducive to the practice of nutrition care
To achieve what outcomes	Both educational and clinical outcomes

Measurement issues

The ultimate aim of health education is to improve health outcomes. Few studies have, however, even tried to show improvements in patients' health because it is very difficult to do. Authors acknowledged that this limited the conclusions they could draw from their evidence [62]), which meant they could often only speculate on how their interventions might affect patients' health. The impact of educational interventions is often ranked according to its position in Miller's pyramid of assessment [83]. Some studies achieved the highest level - the performance level – which is most likely to impact patient outcomes. They did so by directly observing the delivery of nutrition care in clinical settings [14 34 43 45 50], recording videos of doctors counselling patients [14], auditing charts [42 65 84], and using incognito simulated patients [33]. Most studies were at lower levels of the pyramid. For example, they assessed participants' reported changes in practice behaviours by means of self-administered surveys. As observed by the authors of one such study [58], reliance on students' self-reported confidence in counselling rather than an objective measure of counselling skills (such as an objective structured clinical examination) limits the generalizability of the findings. Schlair et al [61] acknowedged the potential for social desirability bias in self-reports. Whilst self-report would be invalid evidence in a systematic review or meta-analysis, it is safer to use it in realist synthesis, which aims to produce progressively more refined theories of change rather than incontrovertible evidence.

For future studies, Scholapio et al [62] suggested that 'harder' data could be obtained using patient surveys and chart reviews, or having participants give specific examples of improved patient outcome that were directly linked to competences they had acquired from educational interventions. Our review shows the need for future studies to explore innovative ways of collecting this information [62].

DISCUSSION

There is increasing pressure for medical education to be socially accountable [85-87]. This research may be seen as socially responsive because it arose out of a pressing health need in sub-Saharan Africa: improvement of the competencies of doctors and other healthcare professionals in order to deliver effective nutrition care. Our study provided practical guidance to educators trying to meet this need in Africa and elsewhere by showing the importance of moving education for nutrition care beyond the simple acquisition of knowledge.

The CMO configurations identified in this realist review are preliminary and non-exhaustive and should be considered as a set of generic hypotheses derived from best available evidence. Nonetheless, they provide information to policy makers about what may improve the nutrition practice behaviour of healthcare professionals, how, under what conditions, and in what settings. Our review has identified a set of conditions that facilitate the success of interventions in varied contexts.

A key finding of this review is that improving the skills, self-efficacy, and attitudes of learners by adopting appropriate teaching and learning strategies is critical to the success of nutrition education interventions. Improving learners' skills and attitudes provides them with confidence and a sense of enactive mastery of the specific tasks they have to perform. Role modelling of the delivery of nutrition care by superiors, providing appropriate physical space in which to deliver nutrition care, and adopting favourable policies are important because they increase professionals' sense of being accepted, credibility, relatedness, and assurance.

Our analysis shows that planners of educational interventions would be well advised to assess potential participants' needs and interests. Computer based education presents new opportunities for course designers and planners. Already considered as a potentially efficient form of teaching and learning in the health professions [47 88-90], this presents novel ways of incorporating nutrition content into healthcare professional curricula. Given that healthcare professionals say they have too little time to attend training programs and provide nutrition care, the convenience of computer-and internet-based education has potential to overcome barriers to learning.

The main strengths of our review were its integrative nature and our use of realist synthesis methodology, which allowed for practical theories to be generated for future testing and implementation. However, the review had limitations. One is that we did not consult individual experts in the field when we developed our initial model. Had we done that, we might have included more candidate theories. We also acknowledge the interpretive and subjective nature of qualitative research and the likelihood that a different team of researchers might have arrived at different candidate program theories. We acknowledge that the model shown in figure 2 is but one of several possible interpretations, as is typical of the models that emerge from realist synthesis. We acknowledge limitations in the evidence base. The synthesis which results from any review is only as good as the primary studies it is able to include. Many of the primary studies provided limited, superficial descriptions of their educational interventions. This made it difficult for us to test all components of our candidate theories and to provide rich descriptions of some of the mechanisms that were identified. As has been found by other reviewers in medical education [22 29 30], this review was limited by a lack of descriptions of the contexts of the intervention, implementation processes, and mechanisms.

Other limitations included the unavailability of the full text of seven studies[91-97]. Whilst it is a limitation, realist synthesis is less dependent on the inclusion of complete sets of studies than, for example, traditional systematic reviews [82]. So, it may limit the scope of our findings but does not invalidate them. Whilst the backbone of metaanalysis and traditional systematic review is aggregation, realist synthesis refines theories by obtaining a rich (rather than necessarily complete) evidence-base of reports of how interventions generate certain pattern of outcome [82]. Finally, initial screening by just one author might be seen as a limitation but we found such high consistency between that author's

judgement and a second author in a pilot phase of the project that we judged single-screening to make best use of the inevitably limited resources in the country, where the research was conducted.

We conclude that it has been possible to assemble, from a heterogeneous database, some patterns in the links between CMOs that are consistent enough to guide the practice of nutrition education. Our findings have refined some existing candidate theories, which researchers, also, apply to their work on nutrition education.

ACKNOWLEDGEMENT

The authors wish to thank Mr. Fuseini Abdulai Braimah, senior library assistant, School of Medicine and Health Sciences, University for Development Studies, Ghana for his support in helping to retrieve full texts of some of the included studies.

FUNDING

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

COMPETING INTEREST

None

Contributors: VM and TD were responsible for the conception and design of the study. VM was principally responsible for searching, sourcing and initial screening of studies. VM, MGC and TD further screened studies based on abstracts. Quality assessment was done by VM, AS, FS and MGC. VM was responsible for data extraction, synthesis and interpretation of the data and drafting of the manuscript. AS, TD, FS, MGC and PA contributed to interpretation of the data and revision of the article. All authors approved the article for publication.

PROVENANCE AND PEER REVIEW: Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT: VM had full access to all the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

REFERENCES

1. Pearson TA, Blair SN, Daniels SR, et al. AHA guidelines for primary prevention of cardiovascular disease and stroke: 2002 update consensus panel guide to comprehensive risk reduction for adult patients without coronary or other atherosclerotic vascular diseases. Circulation 2002;**106**(3):388-91
2. Bantle JP, Wylie-Rosett J, Albright AL, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2008;**31**:S61-S78
3. Goldstein LB, Adams R, Alberts MJ, et al. Primary Prevention of Ischemic Stroke A Guideline From the American Heart Association/American Stroke Association Stroke Council: Cosponsored by the Atherosclerotic Peripheral Vascular Disease Interdisciplinary Working Group; Cardiovascular Nursing Council; Clinical Cardiology Council; Nutrition, Physical Activity, and Metabolism Council; and the Quality of Care and Outcomes Research Interdisciplinary Working Group: The American Academy of Neurology affirms the value of this guideline. Stroke 2006;**37**(6):1583-633
4. United Nations Children's Fund. Improving Child Nutrition:The achievable imperative for global progress. United Nations Children's Fund. New York, 2013:1-124.

5. Kopelman P, Lennard-Jones J. Nutrition and patients: a doctor's responsibility. Clinical Medicine 2002;**2**(5):391-94
6. Council GM. Tomorrow's doctors: Outcomes and standards for undergraduate medical education. Manchester, UK: General Medical Council 2009
7. Abid A, Galuska D, Khan L, Gillespie C, Ford E, Serdula M. Are healthcare professionals advising obese patients to lose weight? A trend analysis. Medscape General Medicine 2004;**7**(4):10
8. Tsai AG, Wadden TA. Treatment of obesity in primary care practice in the United States: a systematic review. Journal of General Internal Medicine 2009;**24**(9):1073-79
9. Abramson S, Stein J, Schaufele M, Frates E, Rogan S. Personal exercise habits and counseling practices of primary care physicians: a national survey. Clinical Journal of Sport Medicine 2000;**10**(1):40-48
10. Huang J, Yu H, Marin E, Brock S, Carden D, Davis T. Physicians' weight loss counseling in two public hospital primary care clinics. Academic Medicine 2004;**79**(2):156-61
11. Laschinger HKS, Tresolini CP. An exploratory study of nursing and medical students health promotion counselling self-efficacy. Nurse Education Today 1999;**19**(5):408-18 doi: 10.1054/nedt.1999.0326[published Online First: Epub Date]|.
12. Jay M, Gillespie C, Ark T, et al. Do internists, pediatricians, and psychiatrists feel competent in obesity care? Journal of General Internal Medicine 2008;**23**(7):1066-70
13. Foster GD, Wadden TA, Makris AP, et al. Primary care physicians' attitudes about obesity and its treatment. Obesity Research 2003;**11**(10):1168-77
14. Tziraki C, Graubard BI, Manley M, Kosary C, Moler JE, Edwards BK. Effect of Training on Adoption of Cancer Prevention Nutrition-Related Activities by Primary Care Practices: Results of a Randomized, Controlled Study. Journal of General Internal Medicine 2000;**15**(3):155-62
15. McLaren DS. Nutrition in medical schools: a case of mistaken identity. American Journal of Clinical Nutrition 1994;**59**(5):960-3
16. Weinsier RL. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1995: medical-nutrition education--factors important for developing a successful program. American Journal of Clinical Nutrition 1995;**62**(4):837-40
17. Gershoff SN. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1996: nutrition education--success or failure? American Journal of Clinical Nutrition 1996;**64**(5):809-12
18. Ball EL, Hughes MR, Leveritt DM. Nutrition in general practice: role and workforce preparation expectations of medical educators. Australian Journal of Primary Health 2010;**16**(4):304-10
19. Mechanic D. Social research in health and the American sociopolitical context: the changing fortunes of medical sociology. Social Science Medicine 1993;**36**(2):95-102
20. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Nutrition training improves health workers' nutrition knowledge and competence to manage child undernutrition: a systematic review. Frontiers in Public Health 2013;**1**:37
21. Mogre V, Scherpbier A, Dornan T, Stevens F, Aryee PA, Cherry MG. A realist review of educational interventions to improve the delivery of nutrition care by doctors and future doctors. Systematic Reviews 2014;**3**:148
22. Wong G, Greenhalgh T, Pawson R. Internet-based medical education: a realist review of what works, for whom and in what circumstances. BMC Medical Education 2010;**10**:12
23. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist synthesis: an introduction: ESRC Research Methods Programme, University of Manchester RMP: Methods Paper 2 2004; ; [http://www.ccsr.ac.uk/methods/ publications/documents/RMPmethods2.pdf].

24. McCormack B, Rycroft-Malone J, DeCorby K, et al. A realist review of interventions and strategies to promote evidence-informed healthcare: a focus on change agency. Implementation Science 2013;**8**:107
25. Pawson R. *Evidence-based policy: A realist perspective*: Sage, 2006.
26. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist review–a new method of systematic review designed for complex policy interventions. Journal of Health Services Research & Policy 2005;**10**(suppl 1):21-34
27. Westhorp G, Walker B, Rogers P, Overbeeke N, Ball D, Brice G. Enhancing community accountability, empowerment and education outcomes in low and middle-income countries: A realist review: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London: London. 2014
28. Pluye P, Robert E, Cargo M, et al. Proposal: A mixed methods appraisal tool for systematic mixed studies reviews. Montréal: McGill University 2011
29. Yardley S, Cottrell E, Rees E, Protheroe J. Modelling successful primary care for multimorbidity: a realist synthesis of successes and failures in concurrent learning and healthcare delivery. BMC Family Practice 2015;**16**:23
30. Jones AC, Shipman SA, Ogrinc G. Key characteristics of successful quality improvement curricula in physician education: a realist review. BMJ Quality & Safety 2015;**24**(1):77-88
31. Steinert Y, Mann K, Centeno A, et al. A systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education: BEME Guide No. 8. Medical Teacher 2006;**28**(6):497-526
32. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. British Medical Journal 2015;**349**:g7647
33. Maiburg BHJ, Rethans JE, Schuwirth LWT, Mathus-Vliegen LMH, van Ree JW. Controlled trial of effect of computer-based nutrition course on knowledge and practice of general practitioner trainees. American Journal of Clinical Nutrition 2003;**77**(4S):1019S-24
34. Pelto GH, Santos I, Gonçalves H, Victora C, Martines J, Habicht J-P. Nutrition counseling training changes physician behavior and improves caregiver knowledge acquisition. The Journal of Nutrition 2004;**134**(2):357-62
35. Levy J, Harris J, Darby P, Sacks R, Dumanovsky T, Silver L. The primary care nutrition training program: An approach to communication on behavior change. Health Promotion Practice 2011;**12**(5):761-68
36. Carson JAS. Pocket tape measure for waist circumference: Training medical students and residents on a simple assessment of body composition. Journal of Nutrition 2003;**133**(2):547S-49S
37. Taren DL, Thomson CA, Koff NA, et al. Effect of an integrated nutrition curriculum on medical education, student clinical performance, and student perception of medical-nutrition training. American Journal of Clinical Nutrition 2001;**73**(6):1107-1112
38. Buckley KM. Evaluation of classroom-based, Web-enhanced, and Web-based distance learning nutrition courses for undergraduate nursing. Journal of Nursing Education 2003;**42**(8):367-70
39. Ray S, Udumyan R, Rajput-Ray M, et al. Evaluation of a novel nutrition education intervention for medical students from across England. BMJ Open 2012;**2**(1) doi: e000417

10.1136/bmjopen-2011-000417[published Online First: Epub Date]|.
40. Ke L-S, Chiu T-Y, Hu W-Y, Lo S-S. Effects of educational intervention on nurses' knowledge, attitudes, and behavioral intentions toward supplying artificial nutrition and hydration to terminal cancer patients. Supportive Care in Cancer 2008;**16**(11):1265-72

41. Buchowski MS, Plaisted C, Fort J, Zeisel SH. Computer-assisted teaching of nutritional anemias and diabetes to first-year medical students. American Journal of Clinical Nutrition 2002;**75**(1):154-61
42. Puoane T, Sanders D, Ashworth A, Ngumbela M. Training nurses to save lives of malnourished children. Curationis 2006;**29**(1):73-78
43. Hillenbrand KM, Larsen PG. Effect of an educational intervention about breastfeeding on the knowledge, confidence, and behaviors of pediatric resident physicians. Pediatrics 2002;**110**(5):e59
44. Ockene JK, Ockene IS, Quirk ME, et al. Physician training for patient-centered nutrition counseling in a lipid intervention trial. Preventive Medicine: An International Journal Devoted to Practice and Theory 1995;**24**(6):563-70
45. Zaman S, Ashraf RN, Martines J. Training in complementary feeding counselling of healthcare workers and its influence on maternal behaviours and child growth: a cluster-randomized controlled trial in Lahore, Pakistan. Journal of Health, Population, and Nutrition 2008;**26**(2):210-222
46. Eisenberg DM, Miller AM, McManus K, Burgess J, Bernstein AM. Enhancing medical education to address obesity:"See one. Taste one. Cook one. Teach one.". JAMA Internal Medicine 2013;**173**(6):470-72
47. Roche PL, Ciccarelli MR, Gupta SK, Hayes BM, Molleston JP. Multi-School Collaboration to Develop and Test Nutrition Computer Modules for Pediatric Residents. Journal of the American Dietetic Association 2007;**107**(9):1586-89 doi: http://dx.doi.org/10.1016/j.jada.2007.06.008[published Online First: Epub Date]|.
48. Gance-Cleveland B, Sidora-Arcoleo K, Keesing H, Gottesman MM, Brady M. Changes in nurse practitioners' knowledge and behaviors following brief training on the healthy eating and activity together (HEAT) guidelines. Journal of Pediatric Health Care 2009;**23**(4):222-30
49. Ray S, Laur C, Douglas P, et al. Nutrition education and leadership for improved clinical outcomes: training and supporting junior doctors to run 'Nutrition Awareness Weeks' in three NHS hospitals across England. BMC Medical Education 2014;**14**:109
50. Bassichetto KC, Réa MF. Infant and young child feeding counseling: an intervention study. Jornal de Pediatria 2008;**84**(1):75-82
51. Dacey M, Arnstein F, Kennedy MA, Wolfe J, Phillips EM. The impact of lifestyle medicine continuing education on provider knowledge, attitudes, and counseling behaviors. Medical Teacher 2013;**35**(5):e1149-e56
52. Ritenbaugh CK, Thomson CA, Taren D, et al. Nutrition curriculum in medical education: An integrated and comprehensive approach. Teaching and Learning in Medicine 1996;**8**(2):102-10
53. Edwards L, Wyles D. The folic acid message–can training make a difference? Journal of Human Nutrition and Dietetics 1999;**12**(4):317-26
54. Castro MG, Pompilio CE, Horie LM, Verotti CCG, Waitzberg DL. Education program on medical nutrition and length of stay of critically ill patients. Clinical Nutrition 2013;**32**(6):1061-66 doi: http://dx.doi.org/10.1016/j.clnu.2012.11.023[published Online First: Epub Date]|.
55. Kohlmeier M, Althouse L, Stritter F, Zeisel SH. Introducing cancer nutrition to medical students: effectiveness of computer-based instruction. American Journal of Clinical Nutrition 2000;**71**(4):873-77
56. Bjerrum M, Tewes M, Pedersen P. Nurses' self-reported knowledge about and attitude to nutrition–before and after a training programme. Scandinavian Journal of Caring Sciences 2012;**26**(1):81-89

57. Pedersen PU, Tewes M, Bjerrum M. Implementing nutritional guidelines–the effect of systematic training for nurse nutrition practitioners. Scandinavian Journal of Caring Sciences 2012;**26**(1):178-85
58. Conroy MB, Delichatsios HK, Hafler JP, Rigotti NA. Impact of a preventive medicine and nutrition curriculum for medical students. American Journal of Preventive Medicine 2004;**27**(1):77-80 doi: http://dx.doi.org/10.1016/j.amepre.2004.03.009[published Online First: Epub Date]|.
59. Endevelt R, Shahar DR, Henkin Y. Development and implementation of a nutrition education program for medical students: A new challenge. Education for Health: Change in Learning & Practice 2006;**19**(3):321-30
60. de Fine Olivarius N, Palmvig B, Andreasen AH, Thorgersen JT, Hundrup C. An educational model for improving diet counselling in primary care A case study of the creative use of doctors' own diet, their attitudes to it and to nutritional counselling of their patients with diabetes. Patient Education and Counseling 2005;**58**(2):199-202
61. Schlair S, Hanley K, Gillespie C, et al. How medical students' behaviors and attitudes affect the impact of a brief curriculum on nutrition counseling. Journal of Nutrition Education and Behavior 2012;**44**(6):653-57
62. Scolapio JS, Dibaise JK, Schwenk WF, 2nd, Macke ME, Burdette R. Advances and controversies in clinical nutrition: the education outcome of a live continuing medical education course. Nutrition in Clinical Practice 2008;**23**(1):90-95
63. Kennelly S, Kennedy N, Rughoobur G, Slattery CG, Sugrue S. An evaluation of a community dietetics intervention on the management of malnutrition for healthcare professionals. Journal of Human Nutrition and Dietetics 2010;**23**(6):567-74
64. Lewis KO, Frank GR, Nagel R, et al. Pediatric trainees' engagement in the online nutrition curriculum: preliminary results. BMC Medical Education 2014;**14**:190
65. Acuna K, Pires C, Santos G, et al. Detection of nosocomial malnutrition is improved in Amazon region by a standard clinical nutrition education program. Nutricion Hospitalaria 2008;**23**(1):60-67
66. Powell-Tuck J, Summerbell C, Holsgrove G, Garrow J. Four years' experience of an undergraduate medical nutrition course. Journal of the Royal Society of Medicine 1997;**90**(2):67-72
67. Afaghi A, Mohamadi AAHA, Ziaee A, Sarchami R. Effect of an Integrated Case-based Nutrition Curriculum on Medical Education at Qazvin University of Medical Sciences, Iran. . Global Journal of Health Science 2012;**4**(1):112-117
68. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition education. American Journal of Preventive Medicine 2002;**23**(4):296-302
69. Vanderpool C, Lin HC, Scheimann A. NASPGHAN Nutrition University as a Model for Continuing Education Within Pediatric Nutrition. Journal of Pediatric Gastroenterology and Nutrition 2014;**58**(4):469-71
70. Duerksen DR. Teaching medical students the subjective global assessment. Nutrition 2002;**18**(4):313-15 doi: http://dx.doi.org/10.1016/S0899-9007(01)00801-2[published Online First: Epub Date]|.
71. Engel SS, Crandall J, Basch CE, Zybert P, Wylie-Rosett J. Computer-assisted diabetes nutrition education increases knowledge and self-efficacy of medical students. Diabetes Educator 1997;**23**(5):545-49
72. Richards D, Mitchell G. Insight. GPs and nutrition: what they want and how they want it. A GP nutrition education project. Australian Journal of Nutrition & Dietetics 2001;**58**(1):56-59
73. Kipp DE. Technological methods in nutrition education. Developing interactive computerized modules accessible on the World Wide Web for medical students. Topics in Clinical Nutrition 1997;**12**(2):38-44

74. Cooksey K, Kohlmeier M, Plaisted C, Adams K, Zeisel SH. Getting nutrition education into medical schools: a computer-based approach. American Journal of Clinical Nutrition 2000;**72**(3):868S-76S
75. Cheatham M, Boosalis MG, Boissonneault GA. Use of a Computer Tutorial on Nutritional Assessment by Three Different Groups of Health Professions Students. Journal of Allied Health 2002;**31**(4):252-55
76. Kolasa KM, Elesha-Adams M, Patton DD. When a reporter calls: media training to teach nutrition education. Topics in Clinical Nutrition 1996;**11**(4):75-80
77. Fox AL. Evaluation of a Pilot Arts and Health Module In a Graduate Community Nutrition Program. Canadian Journal of Dietetic Practice and Research 2009;**70**(2):81-86 doi: 10.3148/70.2.2009.81[published Online First: Epub Date]|.
78. Ockene JK, Kristeller J, Goldberg R, et al. Increasing the efficacy of physician-delivered smoking interventions. Journal of General Internal Medicine 1991;**6**(1):1-8
79. Bandura A, McClelland DC. Social learning theory. Englewood Cliffs, New Jersey: Prentice-Hall 1977
80. Bandura A. *Self-efficacy: The exercise of control*: Macmillan, 1997.
81. Bandura A. Social cognitive theory: An agentic perspective. Annual Review of Psychology 2001;**52**(1):1-26
82. Westhorp G, Walker B, Rogers P. Under what circumstances does enhancing community accountability and empowerment improve education outcomes, particularly for the poor? A realist synthesis protocol. London: EPPI-Centre. Social Science Research Unit, Institute of Education, University of London 2012
83. Miller GE. The assessment of clinical skills/competence/performance. Academic Medicine 1990;**65**(9):S63-7
84. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition eduction. American Journal of Preventive Medicine 2002;**23**(4):296-302 doi: http://dx.doi.org/10.1016/S0749-3797(02)00518-4[published Online First: Epub Date]|.
85. Lindgren S, Karle H. Social accountability of medical education: aspects on global accreditation. Medical Teacher 2011;**33**(8):667-72
86. Boelen C, Woollard R. Social accountability: The extra leap to excellence for educational institutions. Medical Teacher 2011;**33**(8):614-19
87. Boelen C, Woollard B. Social accountability and accreditation: a new frontier for educational institutions. Medical Education 2009;**43**(9):887-94
88. Devitt P, Palmer E. Computer-aided learning: an overvalued educational resource? Medical Education 1999;**33**(2):136-39
89. Carr MM, Reznick RK, Brown DH. Comparison of computer-assisted instruction and seminar instruction to acquire psychomotor and cognitive knowledge of epistaxis management. Otolaryngology--Head and Neck Surgery 1999;**121**(4):430-34
90. D'Alessandro DM, Kreiter CD, Erkonen WE, Winter RJ, Knapp HR. Longitudinal follow-up comparison of educational interventions: multimedia textbook, traditional lecture, and printed textbook. Academic Radiology 1997;**4**(11):719-23
91. Deen D, Karp R, Lowell B. A mini-fellowship in clinical nutrition for primary care physicians. Journal of Cancer Education 2000;**15**(3):134-36
92. Heimburger DC, Ullmann DO, Ramsey MJ, et al. Dietary habits of first-year medical students assessed during clinical nutrition course. Nutrition 1994;**10**(3):214-20
93. Hodgson CS, Wilkerson L, Go VLW. Changes in nutrition knowledge among first- and second-year medical students following implementation of an integrated nutrition curriculum. Journal of Cancer Education 2000;**15**(3):144-47

94. Kolasa KM, Jobe AC, Miller MG, Clay MC. Teaching medical students cancer risk reduction nutrition counseling using a multimedia program. FAMILY MEDICINE-KANSAS CITY- 1999;**31**:200-04
95. Edwards M. Nutrition education for medical students: 4th year transition to residency for primary care (1020.3). The FASEB Journal 2014;**28**(1 Supplement):1020.3
96. Carson JAS. *Impact of integrating cardiovascular nutrition in an ambulatory care rotation on the knowledge, attitudes, self-efficacy and patient care practices of fourth year medical students*, 2000.
97. Baker K, Olfert M. Incorporating nutrition education through applied, hands-on culinary elective in medical school training (1020.2). The FASEB Journal 2014;**28**(1 Supplement):1020.2

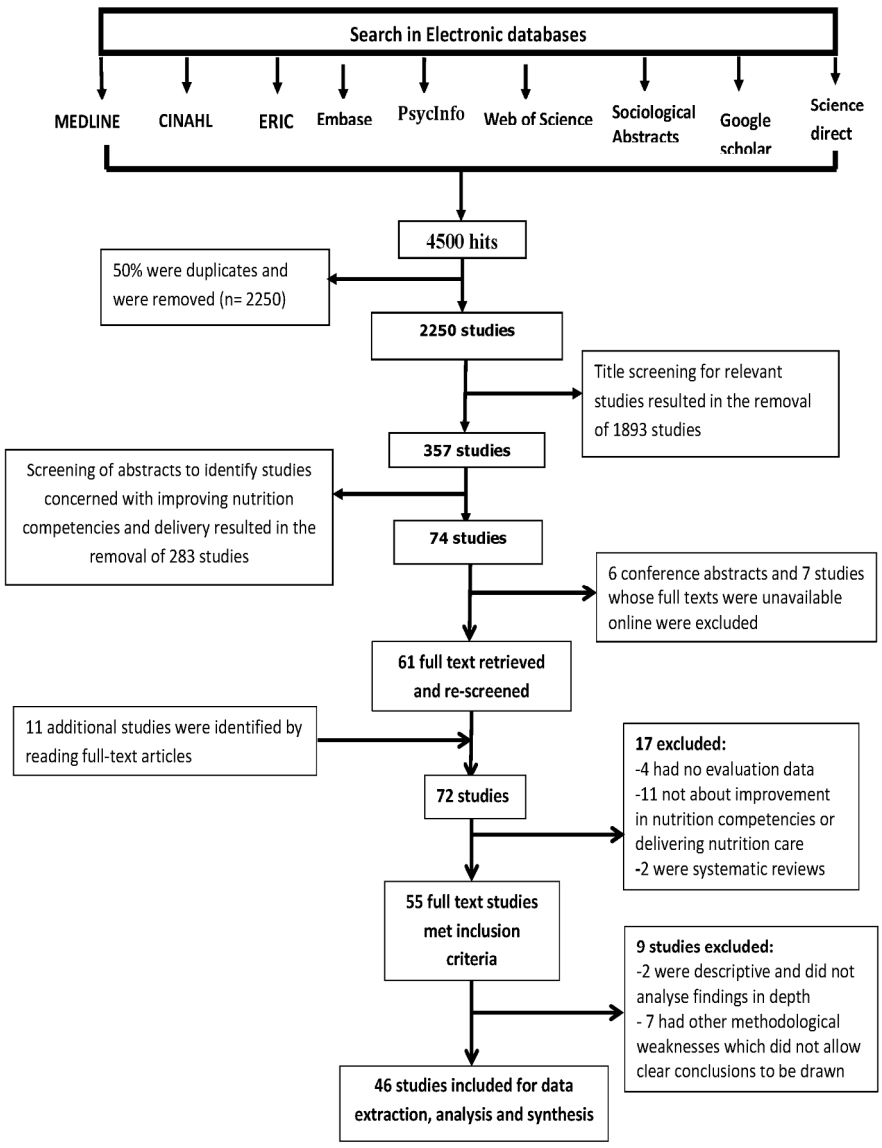


Figure 1: Flow chart of search and selection process

Figure 1: Search and selection process

173x233mm (300 x 300 DPI)

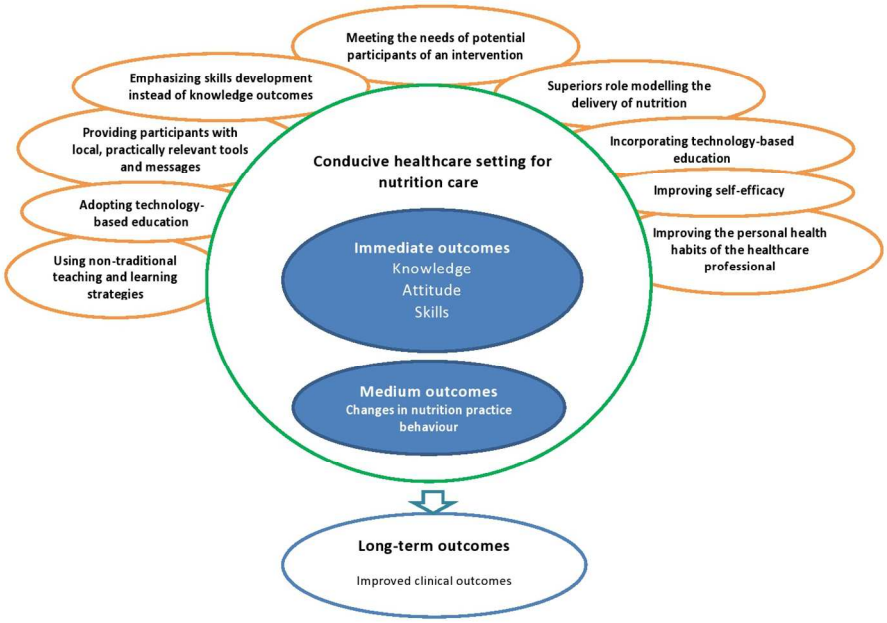


Figure 2: Revised theoretical model or programme theory

Figure 2: Revised thereotical model or programme theory

582x449mm (72 x 72 DPI)

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2, 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4, 5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4, 5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4, 5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6-28
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	NA
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	NA
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	29
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	29
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	29
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.

BMJ Open

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2015-010084.R3
Article Type:	Research
Date Submitted by the Author:	18-Jul-2016
Complete List of Authors:	Mogre, Victor; UNIVERSITY FOR DEVELOPMENT STUDIES, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences Scherpbier, Albert; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Stevens, Fred; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences Aryee, Paul ; University for Development Studies,, Department of Community Nutrition, School of Allied Health Sciences Cherry, Mary; University of Liverpool, Department of Health Services Research, Institute of Psychology, Health and Society Dornan, Timothy; Maastricht University, School of Health Professions Education, Faculty of Health, Medicine and Life Sciences
Primary Subject Heading:	Medical education and training
Secondary Subject Heading:	Nutrition and metabolism, Patient-centred medicine, Public health, Qualitative research, Research methods
Keywords:	EDUCATION & TRAINING (see Medical Education & Training), Public health < INFECTIOUS DISEASES, Nutrition < TROPICAL MEDICINE, Realist review; nutrition; educational interventions; doctors; healthcare professionals

A realist synthesis of educational interventions to improve nutrition care competencies and delivery by doctors and other healthcare professionals

Victor Mogre*[1, 2], Albert J.J.A Scherpbier[2], Fred Stevens[2], Paul Aryee[3], Mary Gemma Cherry[4], & Tim Dornan[2]

[1]Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, School of Medicine and Health Sciences, University for Development Studies, Ghana

[2]School of Health Professions Education, Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands

[3]Department of Community Nutrition, School of Allied Health Sciences, University for Development Studies, Ghana

[4]Department of Health Services Research, Institute of Psychology, Health and Society, University of Liverpool, United Kingdom

*__Corresponding author:__ Victor Mogre, Department of Health Professions Education and Innovative Learning, School of Medicine and Health Sciences, University for Development Studies, P. O. Box TL 1883, Tamale.
Email: vmogre@uds.edu.gh

Key words: Realist review; nutrition; educational interventions; doctors; healthcare professionals

Word count: 5497, four tables, and two figures

ABSTRACT

Objective: To determine what, how, for whom, why, and in what circumstances educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals work?

Design: Realist synthesis following a published protocol and reported following Realist and Meta-narrative Evidence Synthesis: Evolving Standards (RAMESES) guidelines. A multidisciplinary team searched Medline, CINAHL, ERIC, EMBASE, PsyINFO, Sociological Abstracts, Web of Science, Google Scholar, and Science Direct for published and unpublished (grey) literature. The team identified studies with varied designs; appraised their ability to answer the review question; identified relationships between contexts, mechanisms, and outcomes (CMOs); and entered them into a spreadsheet configured for the purpose. The final synthesis identified commonalities across CMO configurations.

Results: Over half of the 46 studies from which we extracted data originated from the US. Interventions that improved the delivery of nutrition care improved skills and attitudes rather than just knowledge; provided opportunities for superiors to model nutrition care; removed barriers to nutrition care in health systems; provided participants with local, practically relevant tools and messages; and incorporated non-traditional, innovative teaching strategies. Operating in contexts where student and qualified healthcare professionals provided nutrition care in both developed and developing countries, these interventions yielded health outcomes by triggering a range of mechanisms, which included: feeling competent; feeling confident and comfortable; having greater self-efficacy; being less inhibited by barriers in healthcare systems; and feeling that nutrition care was accepted and recognised.

Conclusion: These findings show how important it is to move education for nutrition care beyond the simple acquisition of knowledge. They show how educational interventions embedded within systems of healthcare can improve patients' health by helping health students and professionals to appreciate the importance of delivering nutrition care and feel competent to deliver it.

STRENGTHS AND LIMITATIONS OF THIS STUDY

1. Application of the principles of realist synthesis to nutrition and education research is novel.
2. The characteristics and conditions of educational interventions that can improve the delivery of nutrition care, identified by this review, are important to the work of policy makers, researchers, health professions educators, and course developers.
3. Few reports of failed educational interventions were found, indicating a risk of positive publication bias.
4. Until our conceptual model is tested and refined in the real world, we consider it to be an indefinite candidate theory, presenting elements worth considering by those concerned with the design, implementation and evaluation of educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals.
5. We cannot assume that the research evidence we identified represents 'real world' practices, and therefore our claims for the transferability of this research must be guarded.

PROTOCOL

Published at http://www.systematicreviewsjournal.com/content/pdf/2046-4053-3-148.pdf

INTRODUCTION

Nutrition is an important component of healthcare. It plays a critical role in the prevention and treatment of most cardiovascular and cerebrovascular diseases, which are leading causes of morbidity and mortality throughout the world [1-3]. Nutrition is even more important in sub-Saharan Africa because malnutrition is a major cause of morbidity and mortality, particularly among children [4].

Several landmark reports [5 6] have identified the delivery of nutrition care as one of the core responsibilities of doctors. Research has also shown that nutrition counselling delivered by them has positive influence on patients' clinical outcomes. They and other healthcare professionals whose primary role is not nutrition care, however, often miss opportunities to advise patients on diet and health [7 8]. Health workers in primary care settings are particularly important providers of nutrition care because they can motivate even healthy individuals to adopt healthier lifestyles [9]. The care expected from primary care health workers includes nutrition assessment, education and counselling interventions, monitoring, and evaluation. Lack of knowledge [10], skills, and confidence [11 12] as well as negative attitudes towards delivery of nutrition care and low outcome expectancy [13], are barriers to healthcare professionals providing nutrition care. In addition to these individual-related factors, several system-related factors such as lack of time, office space, payment, materials, and education [14] also prevent the delivery of nutrition care by these healthcare professionals.

Many educational interventions have been designed and implemented to improve nutrition care but their effects have been inconsistent and often weak [15-17]. There remains a need, therefore, for interventions that can change healthcare professionals' behaviour in practice [15-17]. It is imperative to identifty contextual factors, which mediate or inhibit their competence and delivery of nutrition care [18 19]. In order to meet those needs, researchers have to identify components of effective educational interventions and processes.

To date, only one secondary research investigation has synthesised conclusions from existing evidence about nutrition care [20]. The authors of that review concluded that in-service nutrition training improved healthcare professionals' knowledge, nutrition-related counselling skills, and malnutrition management skills. The main limitation was that this was a traditional systematic review, which only considered in-service nutrition training programs. Its authors found that the evidence-base was very heterogeneous; studies had widely varying study designs with heterogeneous outcome measures, and there were wide differences in the competence, experience, and backgrounds of participating healthcare professionals. As the authors acknowledged, systematic review methodology limited their ability to recognize and account for the complexity of interactions within such interventions.

We reasoned that we could move the field forward by conceptualizing nutrition education interventions as complex ones within a realist research approach. As noted in our published review protocol [21], we recognised that educational interventions involve multiple actors operating at different levels with a range of artefacts in varied material environments [22]. We assumed that these components operate in non-linear ways to yield context-dependent outcomes. Realist synthesis explores 'what is it about this intervention that works, for whom and in what circumstances?' and is therefore an appropriate way to study complex interventions [23]. It is an iterative, theory-driven approach, which aims to unpack the theories that inform decisions and actions adopted in the design and implementation of interventions [24]. Realist synthesis begins with the development of an initial programme (or candidate) theory about how interventions work, the contexts in which they do and do not work, and the differentiated patterns of outcomes that they generate [25]. As the review progresses, researchers test the initial programme theory and refine it as more evidence becomes available [26].

Thus, the aim of this realist review was to determine what, how, for whom, why, and in what circumstances educational interventions to improve the delivery of nutrition care by doctors and other healthcare professionals work?

METHODS

VM is a nutritionist working in sub-Saharan Africa, which provided a context for the research. Other members of the team included scholars of medical education, evidence synthesis, social science, nutrition, and an experienced clinician.

Alteration from protocol

The review question above is broader than in the published protocol [21] because the search showed important findings from research in health professions other than medicine, which the team felt could make a valuable contribution.

Search methods

Search terms pertaining to nutrition, care, healthcare professionals, training etc. were scoped on two electronic databases. Resulting articles were reviewed and refinement of search terms was not considered necessary. Further explanation and a full list of the search terms can be found in our published protocol [21]. A search strategy was created for Ovid Medline (available in appendix 1) and adapted for the rest of the databases. These databases were CINAHL, ERIC, EMBASE, PsycINFO, Sociological Abstracts, Web of Science, Science Direct and Google Scholar, the latter of which was used to search for grey literature. Email alerts were set for journals and RSS feeds for databases to ensure that we identified new papers as soon as they became available. Email alerts were set for journals and RSS feeds for databases to ensure that we identified new papers as soon as they became available.

Inclusion criteria

- **Study participants:** Medical students, students of other health professions, and practising healthcare professionals (e.g. nurses, physician assistant, etc).
- **Focus of intervention:** Developing participants' competencies in any aspect of nutrition practice behaviour.
- **Study design:** All.
- **Context of intervention:** Medical schools, residency and fellowship programmes, and interventions at both community and hospital settings
- **Publication language:** English.
- **Publication date:** January 1994 to December 2014 inclusive. This date range was chosen because preliminary searches indicated that educational interventions to improve nutrition care competencies and delivery among doctors and other healthcare professionals gained prominence within published literature around 1994.

Exclusion criteria

We sought to understanding generalists' delivery of nutrition education, and therefore we excluded research that only considered the education of dietitians and/or nutritionists since nutrition is their main responsibility. Whilst we excluded conference proceedings, opinion pieces, case studies, and abstracts, we used them to develop the initial candidate theories reported in our protocol [21]. We also excluded systematic reviews, although they informed the design of our data extraction form and provided an insight into context, mechanism, outcome (CMO) configurations and additional references. Papers were also excluded if they lacked evaluation or outcome data and not being about improvement in nutrition care competencies.

Study selection

Figure 1 shows the flow chart of the search and selection processes.The final search yielded 4500 hits. VM and TD initially screened the titles of 100 hits independently and compared their findings. There was almost complete agreement and VM continued with the screening. After eliminating duplicates, 357 studies were selected. Having obtained their abstracts, VM, TD, and MGC determined independently whether each study was concerned with improving nutrition care competencies and delivery of nutrition care. At a face-to-face discussion, we compared our choices, for which the kappa statistic of agreement was 0.9. This yielded 74 studies, six of which were excluded because they were conference abstracts. Seven studies could not be obtained despite repeated attempts. VM read the reference lists of the remainining 61 studies and all identified systematic reviews, identifying 11 more studies.

=Insert figure 1=

Quality assessment

It is regarded as acceptable in realist synthesis to include part(s) or whole studies for analysis and synthesis, provided the methods employed for collecting such data are robust [27]. As recommended by Pawson [25], the appraisal of primary studies was informed by their relevance as well as their rigour [25]. Our judgements of a study's relevance was informed by the extent to which the whole study or parts of it was relevant to our published initial program theory [21]. Our assessment of rigour was informed by the trustworthiness of studies' design, sample size, and data collection tools in relation to the outcomes reported. The Mixed Methods Appraisal Tool [28] helped us assess rigour[28]. Based on the exclusion and inclusion criteria, VM selected 55 of the 72 studies for quality assessment. Quality assessment was conducted by AS, TD, FS and MGC. This process resulted in the exclusion of nine studies from which clear conclusions could not be drawn because of methodological weaknesses. The remaining 46 studies were included into our data analysis. We kept notes of our reasons for including or excluding each study and resolved doubts about our judgements of study quality by discussing between ourselves. The processes of quality assessment and data extraction proceeded concurrently.

Data extraction, analysis and synthesis

For the purposes of data extraction, we followed guidance from previous related systematic reviews [20 22 29-31] and iteratively refined our procedures in accordance with the focus of the review. VM initially extracted data from a sample of 10 studies, discussed the findings with the other members of the team and used those discussions to guide further data extraction. Data extracted included:

- Study design, sample size, outcome data
- Educational levels of study participants (students vs. practising health workers)
- How course material had been developed
- Topics covered
- Methods of teaching and learning
- Methods of evaluating outcomes including data collection tools
- Intervention type (e.g. workshops, curriculum designs)
- Durations of intervention
- Contexts of intervention (e.g. practising healthcare professionals, students)
- Mechanisms generated
- Learning outcomes
- Impacts (if any) of intervention on clinical outcomes
- Any theories or mechanisms postulated by author(s) explaining the effects of interventions

We read all 46 included studies twice, transferring relevant data into our data extraction form. We identified the CMOs and interactions between them for each study as well as the theory informing each intervention. To do that, we assumed that the design of each study was informed by a theory, which the authors stated explicitly or implicitly. Identifying those theories helped us understand how interventions worked to generate outcomes. We discussed and reflected on all the data we had identified for each study, sometimes using extracts of publication narratives to foster reflection.

The next stage was to identify themes that were common to different studies. Using an interpretative and narrative approach, we discussed and synthesised initial conclusions, which we used to refute or refine the candidate theories in our published protocol [21]. We chose this process of synthesis in preference to a metaanalysis, which would not have been possible given the diversity in study populations, designs, interventions, and outcomes [32].

RESULTS

General characteristics of the studies

Table 1 provides a summary of the 46 studies. Twenty-seven (59%) came from the USA; seven (19%) from Europe; four each from South America (all from Brazil) and Asia; two from Canada and one each from Africa (i.e. South Africa) and Australia. In total, 4816 participants participated in them (median = 76 participants; interquartile range: 47, 178). Interventions that had healthcare professionals as participants had somewhat larger numbers (median = 98; interquartile range: 46, 163) than those having students as participants (median = 54 participants; interquartile range: 32, 152).

The studies had varied study designs (shown in table 2) with a preponderance (n=39, 85%) of quasi-experimental designs. Twenty-one studies had follow-up evaluations after the pre-test and post-test evaluations. The time period between post-test and follow-up evaluations ranged between 2 weeks and 12 months.

Most studies (n=32, 70%) evaluated outcomes using surveys of knowledge, attitudes, self-reported practice behaviours, self-efficacy, confidence, and feedback. A large proportion of these surveys were developed by the authors, who did not usually report the psychometric properties of their instruments. All the interventions that set out to improve knowledge used multiple choice questions (ranging between 1 and 78 questions). Changes in attitude before and after interventions were assessed using Likert scales, anchored with statements describing attitudes.

Most questionnaires measuring behaviour changes used self-reported changes in nutrition practice behaviour. A few studies observed clinical behaviour to measure changes in nutrition practice. For example, one study in the Netherlands [33] used incognito standardized patients to assess the impact of an intervention on the nutrition practice behaviour of GP residents. Another study in Brazil [34] measured nutrition indices (i.e.wasting, stunting, and underweight) of children to determine the impact of an educational intervention that aimed to improve the provision of nutrition counselling to mothers and/or care givers by doctors.

Table 1: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Levy *et al* [35]	Workshop	US	Primary healthcare professionals (doctors, nurses, physician assistants)	Pre-and post-test without control group	Training programme to provide information, tools, and technical assistance to primary care practices to improve delivery of preventive services and the management of chronic diseases	• Training well received by all participants • Self-reported improvement in knowledge between pre-and post-test • Self-reported satisfaction with intervention
Carson [36]	Part of an ambulatory Clerkship	US	4th year medical students	Cross-sectional	• Training medical students on assessment of body composition using tape measure • Facilitating the identification and treatment of metabolic syndrome	• Increased self-reported knowledge • Probable changes in practice behaviour
Taren *et al* [37]	Required course	US	Preclinical medical students	Pre-and post-test with control group	• Evaluation of an integrated nutrition education program • Nutrition intervention for disease prevention and therapy	• Significant increase in nutrition OSCE scores between pre-and post-test • Increased self-reported satisfaction in nutrition content of the curriculum
Buckley [38]	Varied formats (web-based, web-enhanced and traditional lectures)	US	4th year nursing students	Cross-sectional	Evaluating the effect of various formats of training on the nutrition knowledge of participants	• No significant changes in knowledge between the three formats • More positive perception of web-enhanced than the web-based and traditional

OSCE = Objectively Structured Clinical Examination

Table 1 Continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ray *et al* [39]	Lectures, demonstrat-ions, and interactive practical sessions	UK	3rd and 4th year clinical students	Pre-and post-test without control group	• Evaluating the effectiveness of a nutrition education intervention in a cohort of tomorrow's doctors using knowledge, attitude and practice scores related to clinical nutrition • Covering topics relating to hospital malnutrition	• Significant improvement in knowledge scores between pre- and post-test • Significant changes in attitude scores • Students reported satisfaction with the course • Applied acquired knowledge to patients
Ke *et al* [40]	Workshop	Taiwan	Nurses in ICU, GI and GS	RCT	• The effects of educational intervention on nurses' knowledge, attitudes and behavioural intentions regarding supplying artificial nutrition and hydration • Coverage of topics such as normal nutrient metabolism, nutrient metabolism for terminal cancer patients, and appropriateness of supplying ANH to terminal cancer patients	• Significant improvement in knowledge between pre and post-test • Significant changes in mean attitude scores • Significant changes in behaviour intentions
Buchowski *et al* [41]	A computer-based and a required course	US	First year medical students	Pre-and post-test without control group	• The efficacy of 2 modules (Nutrition Anaemias and Diabetes and Weight Management) used by first year medical students • Coverage of topics such as nutritional anaemias, diabetes, and weight management	• Increase in knowledge scores between pre- and post-test • Developed positive attitudes towards nutrition after intervention • Mixed results with regard to confidence to counsel patients on nutrition

RCT = Ransomized Controlled Trials; ICU = Intensive Care Unit; GI= Gastroenterology; GS= General Surgery; ANH =Artificial Nutrition and Hydration

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Puoane *et al* [42]	Workshop	South Africa	Nurses	Pre-and post-test without control group	• Assessing the attitudes and perceptions towards severely malnourished children and their mothers/caregivers pre-and post-intervention • Coverage of topics such as principles of care set out by the WHO for managing severe malnutrition	• Positive change in attitudes towards malnourished children after intervention • Change in perceptions about malnourished children after training • Reduction in case fatalities
Hillenbrand and Larsen [43]	Workshop	US	Paediatric residents	Pre-and post-test without control group	The effect of an educational intervention on paediatric residents' knowledge about breastfeeding, their confidence in addressing lactation issues, and their management skills during clinical encounters with breastfeeding mothers.	• Intervention improved the knowledge of paediatric residents about breastfeeding • Confidence increased after the intervention • Limited changes in participants' practice behaviour after intervention
Maiburg [33]	Computer-based instruction	The Netherlands	GP trainees	Pre-and post-test with control group	• The impact of a computer-based instruction on nutrition knowledge and practice behaviour of GP trainees. • Covered a wide range of nutrition including food pyramid, obesity, diabetes mellitus, hypercholesterolemia, hypertension, irritable bowel syndrome	• Improvement in knowledge scores after intervention • Changes in practice behaviour

GP = General Practitioner; WHO = World Health Organisation

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Ockene *et al* [44]	Workshop	US	Internists	RCT	• Impact of a training programme on physicians' lipid intervention knowledge, attitudes and skills • Improved skills on brief dietary risk assessment and patient-centred counselling	• No significant changes in self-reported knowledge scores • Limited changes in attitudes • Counselling scores increased between pre and post-test
Zaman *et al* [45]	Workshop	Pakistan	Healthcare workers	RCT	Impact of training health workers in nutrition counselling in enhancing their communication skills and performance, improving feeding practices, and reducing growth faltering in children aged 6-24 months.	• Improved communication skills • Improved consultation performance • Mothers able to recall recommendations of health workers
Eisenberg *et al* [46]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	Improving healthcare professionals nutrition behavior, personal habits and their perceived ability to advise overweight or obese patients through the inclusion of 'culinary education' in the form of cooking demonstrations and participatory hands-on cooking workshops, combined with more traditional didactic, nutrition-related presentations	• Self-reported significant positive changes in ability to counsel obese patients • Changes in participants' nutrition behaviours

RCT=Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Roche *et al* [47]	Computer-based instruction	US	Paediatric residents	RCT	A computer-based compact disc instructional program covering the nutrition topics of oral rehydration therapy, calcium, and vitamins.	• Modest improvement in self-reported knowledge scores after intervention • Positive attitudes towards computer instruction after intervention • Participants believed intervention enhanced their knowledge in nutrition
Gance-Cleveland [48]	Workshop	US	Nurse practitioners	Pre-and post-test without control group	• Four hour training session on Healthy Eating and Activity Together (HEAT) Clinical Practice Guideline (CPG) to improve provider behaviour and efficacy • Topics covered included obesity prevention, behaviour modifications and family counselling, family collaboration and advising	• Post training results revealed significant improvement in practitioner knowledge • Post training results revealed significant improvement in practitioners' intent to improve behaviour • Post training results revealed significant improvements in practitioners' report of increased confidence in ability to address barriers
Ray *et al* [49]	Workshop	UK	Junior doctors	Pre-and post-test without control group	Nutrition assessment in hospitalised patients	Significant improvement in knowledge, attitudes and practice scores

RCT=Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Bassichetto and Rea [50]	Workshop	Brazil	Paediatricians and nutritionists	RCT	• Training intervention to equip junior doctors to run a hospital nutrition awareness week to contribute to the improvement in nutrition care • Topics covered included clinical and public health nutrition, organisational management and leadership strategies	• Significant improvement in knowledge scores after intervention • Improvement in dietary counselling after intervention
Dacey *et al* [51]	Workshop	US	Doctors and other healthcare professionals	Pre-and post-test without control group	• The impact of two types of live-face-to-face CME programs aiming to alter participants' thinking and behaviour and comfort with the use of lifestyle medicine • Topics included the history and rationale for lifestyle medicine, exercise medicine initiative, and lifestyle medicine competencies	• Improvement in the perception of barriers to lifestyle medicine • Improvement in self-reported knowledge • Increased confidence to counsel
Ritenbaugh *et al* [52]	4-year integrated nutrition curriculum	US	All levels of medical students	Cross-sectional	Evaluation of an integrated nutrition curriculum	• Changes in knowledge • Students satisfied with curriculum

RCT = Randomized Controlled Trial; CME = Continous Medical Education

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Tziraki and Graubard [14]	Workshop	US	Primary care doctors	RCT	• Training to improve the adoption of a manual to guide primary care practices in structuring their office environment and routine visits to improve nutrition screening, advice/referral, and follow-up for cancer prevention • Compared the effect of training on the manual with mailing the manual to practices	• Greater adoption of manual recommend-ations among practices in the training group • Training group adhered closer to diet screening recommendations in the manual • Changes in office environment were conducive to nutrition screening and dietary advice
Edwards and Wyles [53]	Workshop	UK	Healthcare professionals	Pre-and post-test without control group	Effectiveness of training sessions for health professionals concerning folic acid in pregnancy	• Improvement in knowledge after training • Participants enjoyed most parts of the training
Castro *et al* [54]	Workshop	Brazil	Doctors in the ICU	Pre-and post-test with control group	A multifaceted nutritional educational intervention on the quality of nutritional therapy and clinical outcomes of critically ill patients	• Significant improvement in participants' knowledge after the intervention • Reduction in patients' length of stay of in the ICU • Adequacy of nutritional therapy improved significantly • Initiating enteral nutrition earlier than 48 hours more commonly

RCT = Randomized Controlled Trial

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pelto *et al* [34]	Workshop	Brazil	Doctors	RCT	• Training to improve the nutrition counselling behaviour of physicians and caregiver retention of nutrition advice using the nutrition component of the WHO/UNICEF strategy of Integrated Management of Childhood Illness (IMCI) • Reducing growth faltering in children by means of the nutrition training program	• Modest changes in physician behaviour in practice • Mother's uptake of physician advice improved • Reduction in malnutrition cases
Kohlmeier *et al* [55]	Computer-based instruction	US	First year medical students	Pre- and post-test without control group	Evaluating students' attitudes and self-efficacy in nutrition and cancer and acceptability of a computer-based instruction	• Significant improvement in attitudes and self-efficacy after intervention • Students generally accepted computer-based instruction
Bjerrum [56]	Workshop	Denmark	Nurses	Pre-and post-test without control group	• Improving nurses knowledge in nutrition and their attitudes towards their responsibility to providing nutrition care in relation to assessment and management • Coverage of basic nutrition education, malnutrition in the hospital setting	• Changes in knowledge and attitudes • Participants felt more secure in their ability to provide nutrition care • Participants were satisfied with the intervention

RCT = Randomized Controlled Trials; WHO = World Health Organisation; UNICEF = United Nations Children's Fund

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Pedersen *et al* [57]	Workshop	Denmark	Nurses	Pre-and post-test without control group	Training programme to implement nutritional guidelines to change nurses' nutrition practice behaviour relating to the identification of patients' eating habits, improving patients' knowledge about appropriate food choices and number of snacks eaten between meals to risk of undernutrition in hospitalized patients.	• Modest changes in nutrition practice behaviour • Improvement in the eating difficulties of patients • Patients' knowledge of appropriate food choices improved
Conroy *et al* [58]	Required course	US	2nd year medical students	Pre-and post-test without control group	Impact of an innovative Preventive Medicine and Nutrition curriculum on students' confidence about addressing patients' diet and exercise patterns and on their own health habits	• Personal dietary, exercise patterns of participants improved • Confidence in their ability to address diet and exercise in patients increased
Endevelt, Shahar & Henkin [59]	Workshop	Israel	2nd year medical students	Cross-sectional	• Identification of time slots for nutrition training for medical students • Impact of a nutrition education programme on students' knowledge • Topics covered included nutrition and dietary recommendations for healthy people. Health risks of obesity	• Changes in knowledge • Students considered nutrition curriculum to be effective

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Olivarius *et al* [60]	Seminar	US	Primary care doctors	Pre-and post-test with control group	• Improving the quality of diet recording and instruction in primary care • Diet counselling for diabetes patients using one's own diet	• Improvement in personal dietary behaviours of participants • Changes in attitudes towards dietary counselling
Schlair *et al* [61]	Workshop	US	First year medical students	Pre-and post-test without control group	• The feasibility and impact of a brief nutrition-counselling curriculum on medical students' nutrition knowledge, confidence, attitudes and practices and their own affect the students' own nutrition behaviour and attitudes • Topics covered were nutrition-related counselling confidence for patients with obesity and chronic disease and understanding of simple nutrition messages	• Significant changes in self-efficacy scores • Significant changes in attitudes • Improvement in nutrition counselling competence • Improvement in personal dietary habits
Scolapio *et al* [62]	Workshop	US	Doctors, dieticians and pharmacist	Pre and post-test with control group	• Impact of a live continuing medical education nutrition course on participants' nutrition knowledge and practice behaviour. • Coverage of a variety of topics including identifying methods to feed patients with acute pancreatitis, parenteral nutrition, management of obesity, and others.	• Significant changes in knowledge • Confidence in counselling patients on nutrition improved • Modest changes in practice behaviours

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Kennelly *et al* [63]	Workshop	Ireland	GPs and nurses	Pre-and post-test without control group	The impact of a dietetics intervention on healthcare professionals' knowledge in nutrition and practice behaviour related to the management of malnutrition in hospitalized patients and the acceptability of the educational intervention	• Significant changes in knowledge • Modest changes in practice behaviours • Level of acceptance for the intervention increased
Lewis *et al* [64]	Internet-based instruction	US	Paediatric residents	Cross-sectional	• Evaluating paediatric trainees' engagement, knowledge acquisition and satisfaction with nutrition modules delivered in interactive and non-interactive format • Coverage of breastfeeding practices	• Significant change in knowledge • Engagement with course content increased • Level of satisfaction with intervention increased
Acuna *et al* [65]	Workshop	Brazil	Medical and nursing students	Pre-and post-test without control group	• Evaluating the effect of an intensive education course given to health care professionals and students • Topics covered related to hospital malnutrition	Ability to diagnose malnutrition improved
Powell-Tuck *et al* [66]	Required course	US	2nd year medical students	Pre-and post-test without control group	Development and inception of a 7-day curriculum on diet and health	• Students' feedback was positive • Significant changes in knowledge

GPs = General Practitioners

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Afaghi *et al* [67]	Workshop	Iran	Clinical year 4 and 5 students	Pre-and post-test without control group	• Clinical based case study teaching to enhance clinical skills regarding the role of nutrition in chronic disease • Topics covered included the role of nutrition in chronic diseases, assessment of dietary intake and weight management	• Student perceptions of the adequacy of the instruction were positive • Significant changes in knowledge
Carson *et al* [68]	Required course	US	4th year medical students	Pre-post-test with control group	The outcomes of an integrated cardiovascular nutrition in the fourth year of medical school at the University of Texas	• Significant changes in knowledge • Significant changes in attitude • Self-efficacy in addressing nutrition issues improved
Vanderpool *et al* [69]	Continuous medical education	US	Paediatric gastroenterology residents and paediatric gastroenterologists	Pre-and post-test without control group	• Improving nutrition knowledge acquisition and dissemination. • Topics covered included paediatric nutrition and paediatric nutrition assessment	• Changes in knowledge • Changes in behavior • Changes in patient outcomes
Duerksen [70]	Clinical rotation	Canada	Second year medical students	Pre-and post-test without control group	Assessment of hospitalized patients' nutrition using the Subjective Global Assessment (SGA).	• Students correctly identified malnourished patients • Increased confidence in nutritional assessment
Engel *et al* [71]	Computer-based training as part of family practice clerkship rotation	US	Third year medical students	Pre-and post-test without control group	Knowledge and self-efficacy in prescribing diets for patients with diabetes	• Improved changes in knowledge • Improved changes in self-efficacy

Table 1 continued: Summary of findings of studies reviewed (n=46)

Author(s) and year	Intervention type	Study location	Participants	Study design	Focus of intervention/topics covered	Outcomes
Richards & Mitchell [72]	Presentation by a dietitian to individual participants	Australia	GPs	Pre-and post-test without control group	Presentation of a nutrition manual and behaviour modification strategies	• Improved confidence to provide specific nutrition information and dietary recommendations • Increase in the use of the nutrition manual • Nutrition counselling of patients improved
Kipp [73]	Computer-based instruction	US	First year medical students	Pre-and post-test without control group	Evaluation of a CAI module on food Guide Pyramid and dietary guidelines	• Students considered CAI as appropriate learning tool for nutrition concepts • Students satisfied with format • Changes in knowledge
Cooksey *et al* [74]	Computer-based instruction	US	Pre-clinical medical students	Cross-sectional	Evaluation of series of interactive, multimedia educational programs (Nutrition in Medicine) that teach the basic principles of nutritional science and application to cases	Advantages of accessibility, self-paced study, interactivity, immediate feedback, and tracking students' performance were noted
Cheatham *et al* [75]	Computer-based tutorial	US	Nursing, physician assistant and physical therapy students	Pre-and post-test without control group	Development and use of a computer-based tutorial on nutritional assessment	• Significant changes in knowledge scores • Students felt amount of content was adequate
Kolasa *et al* [76]	Workshop	US	Dietetic students, family medicine residents and third year medical students	Cross-sectional	Encouraging effective communication with both media and consumer through article preparation	Participants found the intervention to be an interesting way to learn about current food and nutrition issues
Fox [77]	Required course	Canada	Community nutrition graduate students	Pre-and post-test without control group	Incorporation of arts as strategies for understanding and addressing community health issues.	Students recognised the incorporation of arts as a mechanism of conducting health research, advocacy, education, healing, and capacity-building initiatives

GPs=General Practitioners; Computer-Assisted Instruction

Intervention focus, types, teaching and learning formats, duration of interventions and expected learning outcomes

Only 11 studies (24%) explicitly stated the theoretical underpinning of their interventions. These included experiential, social, and cognitive learning theories as well as cognitive theory of multimedia learning. The purpose of most interventions was to improve participants' competencies (i.e. knowledge, skills and attitudes) in a variety of nutrition topics (shown in table 1). Studies originating from developing countries tended to cover topics related to infant and young child feeding practices, whereas those from developed countries covered topics relating to hospital malnutrition and nutritional management of chronic diseases. Most studies in which students participated aimed to increase curriculum contact hours and nutrition content. Studies involving practitioners were usually CME programs aiming to improve knowledge, attitudes, skills, and practice behaviour in specific topics such as breastfeeding practices and dietary counselling. Teaching and learning formats included lectures, problem-based learning tutorials, nutrition slogans, demonstrations, role plays, group discussions, games, and video presentations. All interventions used more than one teaching and learning format except six, which were either lecture-based or computer-based only [33 40 47 55 64 69]. Almost all the interventions used innovative teaching and learning methods. Interventions involving students were usually obligatory and lasted from between two weeks to four years. Those involving professionals were generally shorter. The shortest intervention was a one-hour intensive session for general practitioners and other healthcare professionals on the benefits of giving folic acid to women of childbearing age [53]; the longest were two four-year integrated nutrition curricula for medical students [37 52]. Inconsistent reporting of the length of interventions (including use of terms like credit hours) made it difficult to determine their average lengths.

Table 2: Study designs and data collection methods

Characteristic	Frequency (%)
Study design	
Randomised control trials	7(15%)
Quasi-experimental	
Pre-test-post-test with control group	6(13%)
Pre-test-post-test without control group	26(57%)
Cross-sectional	7(15%)
Methodological approach	
Qualitative	5(10%)
Quantitative	32(70%)
Both qualitative and quantitative	9(20%)
Data collection method	
Questionnaires/surveys only	32(70%)
Observations only	2(4%)
Focus group discussions only	2(4%)
Questionnaires/survey with other methods (e.g. interviews, observations)	10(22%)
Format of intervention	
Training programs	12(26%)
Workshops	9(20%)
Required courses	7(15%)
Technology-based (computer-based, internet-based)	11(24%)
Ambulatory clinical rotations	2(4%)
Seminars	1(2%)
Continuing medical education programs	4(9%)
Healthcare professionals (n=22, 48%)	
Doctors (general practitioners/primary care)	8(36%)
Nurses	5(23%)
Multidisciplinary participants (e.g. nurses, doctors, pharmacists)	9(41%)
Students (n=24, 52%)	
Undergraduate, preclinical	14(58%)
Undergraduate, clinical	5(21%)
Postgraduate	5(21%)

Context-Mechanisms-Outcomes Configurations

Table 3 lists the CMOs identified from the included studies. We describe here how those interacted to yield CMO configurations.

Emphasizing skills development instead of knowledge outcomes ("Let me be skilful")

Researchers were often triggered to design interventions by professionals' lack of knowledge about nutrition. This was particularly true of undergraduate education [38 41 59 64 66 67], where all but one [53] of the interventions primarily targeting knowledge took place. Yet interventions that only aimed to improve knowledge were less likely to change practice behaviour. In four studies, for example, significant gains in knowledge did not predict practice scores [39], improve students' assessment of the nutrition status of overweight patients [36], influence behaviour change intentions [40], or affect dietary counselling for mothers/caregivers of children aged 12-24 months [50]. Furthermore, there were interventions, which did not significantly increase knowledge yet changed behaviour. For example, a significant improvement in diet counselling during audiotaped physician-patient interactions [44 51] and increased self-reported counselling behaviour and confidence [51] took place without any significant increase in knowledge. In one study, Ockene et al [44] noted that 'a large proportion (1.5 hour) of the entire 3-hour CME training program was devoted to the learning of counselling and dietary assessment skills'. These findings show that it is important to train skills and create learning environments that encourage the acquisition of skills in order to change healthcare professionals' nutrition care behaviour [78 79].

Table 3: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Participants lacking nutrition counselling skills • Participants having inadequate knowledge • Participants being future and practising healthcare professionals	Emphasizing skills building instead of knowledge outcomes ("let me be skillful")	• Being more confident • Feeling adequately prepared	• Use of dietary counselling steps • Self-reported confidence to counsel patients and change in counselling behaviour
• Lack of faculty to provide nutrition training at both preclinical and clinical settings • Participants being future and practising healthcare professionals	Superiors role modelling the delivery of nutrition care ("I look up to you")	• Being more confident • Sense of acceptance • Sense of credibility • Anticipation of being valued	• Better delivery of nutrition care in clinical settings • Greater confidence in nutrition counselling
Participants being future and practising healthcare professionals	Meeting the needs of potential participants of an intervention ("Ask me what I want")	• Interest • Sense of knowing the needs of participants	• Greater satisfaction with educational intervention • Signicant gains in knowledge outcomes
• Participants lacking time to provide nutrition care • Lack of payment for providing preventive care • Participants having limited access to referral sources and materials for nutrition care • Poor investment into nutrition care • Lack of supportive office systems to deliver nutrition care • Separation of prevention and curative services in the health care system	Addressing structural and systemic factors to make an enabling environment ("Is my consulting room enabling?")	• Feeling comfortable to deliver nutrition care • Sense of acceptance • Perceiving fewer barriers to the delivery of nutrition care • Sense of recognition	• Structured office environment conducive to providing nutrition-related services • Strategies to address lack of support systems • Encountering fewer barriers to lifestyle medicine

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Inadequate instruction and syllabi for nutrition training in curricula • Busy healthcare professionals lacking time to attend continuing education programs in nutrition	Incorporating technology-based education ("My computer is a learning tool")	• Convenience and self-paced study • Interactivity • Instant feedback • Accessibility	• Significant gains of knowledge • More positive attitudes towards nutrition care • Changed real-time practice behaviour • Greater confidence in skills of nutrition counselling • Better counselling skills
• Practising health care professionals • Participants lacking appropriate tools to deliver nutrition care • Participants' personal dietary and lifestyle habits • Participants having inadequate training in nutrition • Participants not routinely addressing patients' nutrition problems • Existence of structural barriers to providing nutrition care to patients	Providing participants with local, practical relevant tools and messages ("Give me tools")	• Removal of perceived barriers • Feeling comfortable	• Facilitating the uptake of nutrition messages • Changed nutrition practice behaviour • Engaging in specific rather than general discussion with patients • Giving relevant advice and recommendations to patients • Simplifying complex messages
Poor interest in nutrition education	Use of non-traditional teaching strategies ("Using the right strategy for the right job")	• Capture interest of participants • Meet the learning needs of participants • Active participation and uptake of knowledge and skills • Relevance of learning	• Engaging the management of malnutrition • Engaging in exercise and dietary counselling • Ability to counsel overweight/obese patients • Significant changes in knowledge gains • Positive personal health habits of participants

Table 3 continued: Context, mechanism and outcome configurations

Context	Intervention characteristics	Mechanisms triggered	Outcomes
• Lack of confidence to deliver nutrition care • Among both future and practising healthcare professionals	Improving self-efficacy ("I feel that I can do it, so I will do it")	• Feeling motivated • Feeling confident	• Self-reported changes in practice behaviours • Intentions to change behaviour
• Participants having inadequate knowledge • Among both future and practising healthcare professionals • Participants lacking training in diet counselling • Lack of patient motivation to change dietary pattern • Lack of time	Improving the personal health habits of healthcare professionals ("Do as I do")	• Being more confident • Sense of being a role model • Sense of relatedness to patients	• Greater counselling confidence • Intentions to change behaviour • Positive healthy lifestyles • Engaging in dietary assessment • More favourable attitudes towards nutrition counselling
• Low priority given to nutrition • Inadequate time dedicated to nutrition • Healthcare students • Reported inadequate knowledge in nutrition	Integrating nutrition content ("Add nutrition to my learning")	• Accepting nutrition education • Reduction in perception of time limitations	• Greater recognition of the relevance of nutrition education • Increased in the number hours dedicated to nutrition • Greater gains in cognitive outcomes
• Multidisciplinary nature of healthcare delivery • Cross-disciplinary nature of nutrition	Adopting a multidisciplinary approach in intervention design and implementation ("Working with others")	• Sense of belonging • Acceptance • Recognising the multidisciplinary nature of nutrition healthcare delivery	• Multi-disciplinary designed program • Meets the needs of all participants • Greater satisfaction

Superiors role modelling the delivery of nutrition care ("I look up to you")

A candidate theory in our published protocol [21], that healthcare professionals would be more likely to deliver nutrition care if they saw their superiors model the same behaviour, was apparent in the evidence. Seeing superiors model nutrition care led research participants to feel more confident, accepted, and credible. They anticipated their actions being valued, which led them towards changing their nutrition practice. Virtual physician mentors [41], simulation of GP consultations using video clips [33], physicians describing how they addressed nutrition in practice [68], and role modelling by physicians in classes [68] were among the interventions which provided positive role modelling.

Meeting the needs of potential participants of an intervention ("Ask me what I want")

Most interventions were modelled on the theory that education will be most successful when it is designed to meet participants' needs [35 36 39 49 51 53 59 62 63 67-69]. Needs assessment identified gaps in learners' knowledge or practice behaviour [62], and how they learned best. It informed the content, format, and design of curricula. It helped select teaching and learning methods to which participants were receptive, which they found interesting and satisfying, and which led them to value their education.

Addressing structural and systemic factors ("Is my consulting room enabling?")

As well as education, interventions that improved working environments influenced participants' behaviour and helped maintain changes that had been achieved [57]. Eight studies helped participants address lack of support [35 48 49 69] and systematic barriers [14 34 51 57]. They restructured office environments to make them more conducive to providing nutrition care [14]. Pelto et al [34], for example, stated that 'structural conditions in the public health system in Pelotas provided an environment in which physicians could utilize their knowledge'(p360). Other researchers provided nutritional messages that busy primary care providers could deliver to patients [35]. Presentations on change management and leadership [49] and provision of guidelines on office organization [14] helped improve nutrition care. Collaboration between education and care delivery leaders helped remove structural and systemic barriers [30]. These created working environments that were conducive to the delivery of nutrition care.

Incorporating technology-based education ("My computer is a learning tool")

Seven studies used technology to resolve challenges relating to healthcare professionals having insufficent time to attend continuing education programs, programs having inadequate nutrition content, and faculty being unavailable to teach [33 41 47 55 64 68 74]. Computer-based and internet-based interventions allowed easy updating of content [33], permitted self-directed and independent study of nutrition information [33 47], presented content consistently [68], were accessible [74], promoted interactivity [74], and were convenient for participants because they were self-administered [33 68] and self-paced [74]. These interventions led to significant gains of knowledge [41 47 55 64], positive attitudes [33 47], increase in self-assessed nutrition counselling skills [33 55], and real-time practice behaviour [33]. The convenience, interest, and independent nature of this type of education contributed to those outcomes.

Providing participants with local, practically relevant tools and messages ("Give me tools")

Some researchers theorised that making local, practically relevant tools and messages available in practice contexts would change the behaviour of trainee healthcare professionals. The tools they provided included memorable slogans [35], simple 'key take home messages' [35 39 42 63], personalized nutrition messages [35], and locally relevant examples [34]. Researchers simplified nutrition messages [35], provided resource materials and tools to resolve problems in counselling and

assessing patients [34 63], and adapted advice for local conditions [34]. Those interventions helped professionals engage in specific rather than generic discussions with patients, and provide advice and recommendations that patients found relevant [34]. The authors of an RCT, which improved physicians' counselling of mothers with malnourished children aged 12-24 months in Brazil [34], attributed children's improved nutritional status to this provision of locally appropriate messages and tools.

Using non-traditional teaching and learning strategies ("The right strategy for the right job")

Another theory, which guided interventions, was that non-traditional teaching and learning strategies would change professionals' behaviour. For instance, Hillenbrand *et al*. [43] hypothesized that providing a series of interactive educational interventions to paediatric residents would increase their knowledge about breastfeeding and lactation problems and increase their confidence to counsel breastfeeding women. Interventions, which sometimes complemented lectures, included discussions, simulated patient cases, group work, role plays, hands-on demonstrations, group practice, panel discussions and case-based learning. Other interventions included problem-based learning tutorials, computer or web-based cases, student-led debates, self-assessment exercises, and clinical case presentations [58 62 68]. These interventions provided practical experience and promoted active learning. They emphasised the development of skills rather than just knowledge. They engaged participants' interest and helped them assume responsibility for their own learning. These interventions caused significant changes in participants' knowledge, personal health habits, confidence to provide exercise and dietary counselling, ability to counsel obese patients, and ability to manage malnutrition. Carson *et al.* [68]attributed the enhanced nutrition counselling skills of students in a four week ambulatory care rotation to their innovative combination of teaching strategies.

Improving self-efficacy ("I feel that I can do it, so I will do it")

Self-efficacy is a basic tenet of Bandura's social learning theory [80]. This term describes individuals' confidence in their ability to perform a task or achieve an outcome. It is a key influence on behaviour [80]. Eight studies explicitly set out to improve participants' self-efficacy by increasing their confidence. They adopted strategies like role modelling by practising physicians[68], role playing using either simulated or real patients [43 44 48 58], providing demonstrations and hands on practice sessions [35 43 44 46 48 61 68], and viewing then discussing videos and web-based cases [44 68]. Four each of these interventions were conducted among future healthcare professionals and practising healthcare professionals. They were effective in both settings.

Improving the personal health habits of the healthcare professional ("Do as I do")

Four interventions, which stimulated practising [46 60] and health professions students [58 61] to take better care of their own health, had positive outcomes. These included regular consumption of fruits and vegetables, personal awareness of calorie consumption, engagement in regular physical activity, and development of culinary skills. In both settings, these led to better self-reported healthy lifestyles and self-reported ability to undertake dietary assessment [61], counselling confidence [46 58 61], self-assessed knowledge [60] and even treating a higher proportion of diabetic patients with diet alone [60]. Healthcare professionals, who considered themselves role models for patients, felt more confident to advise patients to do as they had done [46 58 61].

Initial and revised programme theory

Our published protocol [21] presented candidate theories, and a theoretical model, which we briefly repeat here. Drawing on social cognitive theory, we postulated that:

- Healthcare professionals' ability to deliver nutrition care is influenced by their competence, which is the outcome of a learning process, which is influenced by factors within academic environments. Those factors include the quantity and quality of nutrition content in curricula, the teaching and learning methods employed, and the extent to which learning is reinforced.
- Professionals are more likely to care for patients' nutrition if they have high self-efficacy for nutrition care and vice versa.
- Professionals' delivery of nutrition care is a behaviour demonstrated in the social context of workplaces, which is influenced by observing and modelling the behaviours, attitudes and emotional reactions of others (e.g. superiors) [81]. It is also influenced by the structural determinants of behaviours such as the workplace settings themselves (e.g. hospital/community, emergency/paediatric/general ward), job descriptions/role, time and availability of other staff to undertake particular roles.

The review process described above examined those theories, which led us to revise, add components to, and broaden our theoretical model (shown in figure 2). 'Outcomes', in realist terminology, can be short, medium and long-term [82]. We have added a hierarchy of outcomes to our theoretical model.

The items in the model are interrelated as opposed to operating in isolation from one another. They do not operate in a linear fashion. Several context-mechanism-outcome configurations could be generated from the data. For instance, needs assessments identifies knowledge, skills and attitude gaps and other educational needs of potential participants. The outcome of the needs assessments informs the design of the educational intervention as well as its characteristics. It informs what kind of characteristics, or strategies the intervention should adopt in order to realise the desired outcome. These strategies could include improving the personal health habits of healthcare professionals, adopting technology-based education, improving skills development, adopting innovative teaching and learning strategies, role modelling, and others. These generate mechanisms (not indicated in the diagram) such as interest, receptivity, and acceptance, which generate short-term outcomes such as improved knowledge, attitude, skills, self-efficacy, values and personal habits. The immediate and short-term outcomes may act as mechanisms to bring about change in nutrition practice behaviour (medium-term outcome). Doctors and other healthcare professionals may change their nutrition practice behaviour as a result of having adequate knowledge, skills, attitudes, confidence and self-efficacy. A change in nutrition practice behaviour will mean increased delivery of nutrition care to patients which may result in the long-term goal of improved clinical outcomes (long-term outcomes) of patients. However, these outcomes can best be enhanced and maintained if there is an enabling health care setting (context). This could be realised by enhancing certain conditions/contexts such as restructuring the healthcare system, removing structural and systemic barriers, adopting favourable policies for nutrition care, providing appropriate tools to deliver nutrition care, investing more in preventive care, and providing an office that makes it easier to provide nutrition care. Providing an enabling healthcare setting was central to all the CMO configurations identified.

=Insert figure 2=

We present in table 4 a summary of the characteristics of interventions in accordance with what works, for whom, and under what conditions.

Table 4: Overview of what works, for whom, under what circumstances, to achieve what?

What works	Choosing interventions, which are educationally and clinically relevant to the needs of participants Adopting appropriate teaching and learning techniques Building on self-efficacy and confidence through role modelling Emphasizing skills development rather than pure knowledge gains Improving the personal lifestyle habits of healthcare professionals Removing systemic barriers and restructuring healthcare systems to make healthcare settings more enabling Using practical, relevant tools Using Information and Communications Technology (computer-based education)
For whom	Doctors and other practising healthcare professionals Students of the health professions
Under what circumstances	Within a multidisciplinary approach to nutrition education and care Supported by both educational and care delivery leaders Where nutrition care is recognized as an important component of: Care delivery systems Curricula Where healthcare systems are structured to be conducive to the practice of nutrition care
To achieve what outcomes	Both educational and clinical outcomes

Measurement issues

The ultimate aim of health education is to improve health outcomes. Few studies have, however, even tried to show improvements in patients' health because it is very difficult to do. Authors acknowledged that this limited the conclusions they could draw from their evidence [62]), which meant they could often only speculate on how their interventions might affect patients' health. The impact of educational interventions is often ranked according to its position in Miller's pyramid of assessment [83]. Some studies achieved the highest level - the performance level – which is most likely to impact patient outcomes. They did so by directly observing the delivery of nutrition care in clinical settings [14 34 43 45 50], recording videos of doctors counselling patients [14], auditing charts [42 65 84], and using incognito simulated patients [33]. Most studies were at lower levels of the pyramid. For example, they assessed participants' reported changes in practice behaviours by means of self-administered surveys. As observed by the authors of one such study [58], reliance on students' self-reported confidence in counselling rather than an objective measure of counselling skills (such as an objective structured clinical examination) limits the generalizability of the findings. Schlair et al [61] acknowedged the potential for social desirability bias in self-reports. Whilst self-report would be invalid evidence in a systematic review or meta-analysis, it is safer to use it in realist synthesis, which aims to produce progressively more refined theories of change rather than incontrovertible evidence.

For future studies, Scholapio et al [62] suggested that 'harder' data could be obtained using patient surveys and chart reviews, or having participants give specific examples of improved patient outcome that were directly linked to competences they had acquired from educational interventions. Our review shows the need for future studies to explore innovative ways of collecting this information [62].

DISCUSSION

There is increasing pressure for medical education to be socially accountable [85-87]. This research may be seen as socially responsive because it arose out of a pressing health need in sub-Saharan Africa: improvement of the competencies of doctors and other healthcare professionals in order to deliver effective nutrition care. Our study provided practical guidance to educators trying to meet this need in Africa and elsewhere by showing the importance of moving education for nutrition care beyond the simple acquisition of knowledge.

The CMO configurations identified in this realist review are preliminary and non-exhaustive and should be considered as a set of generic hypotheses derived from best available evidence. Nonetheless, they provide information to policy makers about what may improve the nutrition practice behaviour of healthcare professionals, how, under what conditions, and in what settings. Our review has identified a set of conditions that facilitate the success of interventions in varied contexts.

A key finding of this review is that improving the skills, self-efficacy, and attitudes of learners by adopting appropriate teaching and learning strategies is critical to the success of nutrition education interventions. Improving learners' skills and attitudes provides them with confidence and a sense of enactive mastery of the specific tasks they have to perform. Role modelling of the delivery of nutrition care by superiors, providing appropriate physical space in which to deliver nutrition care, and adopting favourable policies are important because they increase professionals' sense of being accepted, credibility, relatedness, and assurance.

Our analysis shows that planners of educational interventions would be well advised to assess potential participants' needs and interests. Computer based education presents new opportunities for course designers and planners. Already considered as a potentially efficient form of teaching and learning in the health professions [47 88-90], this presents novel ways of incorporating nutrition content into healthcare professional curricula. Given that healthcare professionals say they have too little time to attend training programs and provide nutrition care, the convenience of computer-and internet-based education has potential to overcome barriers to learning.

The main strengths of our review were its integrative nature and our use of realist synthesis methodology, which allowed for practical theories to be generated for future testing and implementation. However, the review had limitations. One is that we did not consult individual experts in the field when we developed our initial model. Had we done that, we might have included more candidate theories. We also acknowledge the interpretive and subjective nature of qualitative research and the likelihood that a different team of researchers might have arrived at different candidate program theories. We acknowledge that the model shown in figure 2 is but one of several possible interpretations, as is typical of the models that emerge from realist synthesis. We acknowledge limitations in the evidence base. The synthesis which results from any review is only as good as the primary studies it is able to include. Many of the primary studies provided limited, superficial descriptions of their educational interventions. This made it difficult for us to test all components of our candidate theories and to provide rich descriptions of some of the mechanisms that were identified. As has been found by other reviewers in medical education [22 29 30], this review was limited by a lack of descriptions of the contexts of the intervention, implementation processes, and mechanisms.

Other limitations included the unavailability of the full text of seven studies[91-97]. Whilst it is a limitation, realist synthesis is less dependent on the inclusion of complete sets of studies than, for example, traditional systematic reviews [82]. So, it may limit the scope of our findings but does not invalidate them. Whilst the backbone of metaanalysis and traditional systematic review is aggregation, realist synthesis refines theories by obtaining a rich (rather than necessarily complete) evidence-base of reports of how interventions generate certain pattern of outcome [82]. We also consider as a limitation the delay in preparing the review for publication after the end of the search in December 2014. During this period new studies might have been published, the inclusion of which may enrich further our

findings. Finally, initial screening by just one author might be seen as a limitation but we found such high consistency between that author's judgement and a second author in a pilot phase of the project that we judged single-screening to make best use of the inevitably limited resources in the country, where the research was conducted.

We conclude that it has been possible to assemble, from a heterogeneous database, some patterns in the links between CMOs that are consistent enough to guide the practice of nutrition education. Our findings have refined some existing candidate theories, which researchers, also, apply to their work on nutrition education.

ACKNOWLEDGEMENT
The authors wish to thank Mr. Fuseini Abdulai Braimah, senior library assistant, School of Medicine and Health Sciences, University for Development Studies, Ghana for his support in helping to retrieve full texts of some of the included studies.

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

COMPETING INTEREST
None

Contributors: VM and TD were responsible for the conception and design of the study. VM was principally responsible for searching, sourcing and initial screening of studies. VM, MGC and TD further screened studies based on abstracts. Quality assessment was done by VM, AS, FS and MGC. VM was responsible for data extraction, synthesis and interpretation of the data and drafting of the manuscript. AS, TD, FS, MGC and PA contributed to interpretation of the data and revision of the article. All authors approved the article for publication.

PROVENANCE AND PEER REVIEW: Not commissioned; externally peer reviewed.

DATA SHARING STATEMENT: VM had full access to all the data in the study, and takes responsibility for the integrity of the data and the accuracy of the data analysis.

REFERENCES

1. Pearson TA, Blair SN, Daniels SR, et al. AHA guidelines for primary prevention of cardiovascular disease and stroke: 2002 update consensus panel guide to comprehensive risk reduction for adult patients without coronary or other atherosclerotic vascular diseases. Circulation 2002;**106**(3):388-91
2. Bantle JP, Wylie-Rosett J, Albright AL, et al. Nutrition recommendations and interventions for diabetes: a position statement of the American Diabetes Association. Diabetes Care 2008;**31**:S61-S78
3. Goldstein LB, Adams R, Alberts MJ, et al. Primary Prevention of Ischemic Stroke A Guideline From the American Heart Association/American Stroke Association Stroke Council: Cosponsored by the Atherosclerotic Peripheral Vascular Disease Interdisciplinary Working Group; Cardiovascular Nursing Council; Clinical Cardiology Council; Nutrition, Physical Activity, and Metabolism Council; and the Quality of Care and Outcomes Research Interdisciplinary Working Group: The American Academy of Neurology affirms the value of this guideline. Stroke 2006;**37**(6):1583-633

4. United Nations Children's Fund. Improving Child Nutrition:The achievable imperative for global progress. United Nations Children's Fund. New York, 2013:1-124.
5. Kopelman P, Lennard-Jones J. Nutrition and patients: a doctor's responsibility. Clinical Medicine 2002;**2**(5):391-94
6. Council GM. Tomorrow's doctors: Outcomes and standards for undergraduate medical education. Manchester, UK: General Medical Council 2009
7. Abid A, Galuska D, Khan L, Gillespie C, Ford E, Serdula M. Are healthcare professionals advising obese patients to lose weight? A trend analysis. Medscape General Medicine 2004;**7**(4):10
8. Tsai AG, Wadden TA. Treatment of obesity in primary care practice in the United States: a systematic review. Journal of General Internal Medicine 2009;**24**(9):1073-79
9. Abramson S, Stein J, Schaufele M, Frates E, Rogan S. Personal exercise habits and counseling practices of primary care physicians: a national survey. Clinical Journal of Sport Medicine 2000;**10**(1):40-48
10. Huang J, Yu H, Marin E, Brock S, Carden D, Davis T. Physicians' weight loss counseling in two public hospital primary care clinics. Academic Medicine 2004;**79**(2):156-61
11. Laschinger HKS, Tresolini CP. An exploratory study of nursing and medical students health promotion counselling self-efficacy. Nurse Education Today 1999;**19**(5):408-18 doi: 10.1054/nedt.1999.0326[published Online First: Epub Date]|.
12. Jay M, Gillespie C, Ark T, et al. Do internists, pediatricians, and psychiatrists feel competent in obesity care? Journal of General Internal Medicine 2008;**23**(7):1066-70
13. Foster GD, Wadden TA, Makris AP, et al. Primary care physicians' attitudes about obesity and its treatment. Obesity Research 2003;**11**(10):1168-77
14. Tziraki C, Graubard BI, Manley M, Kosary C, Moler JE, Edwards BK. Effect of Training on Adoption of Cancer Prevention Nutrition-Related Activities by Primary Care Practices: Results of a Randomized, Controlled Study. Journal of General Internal Medicine 2000;**15**(3):155-62
15. McLaren DS. Nutrition in medical schools: a case of mistaken identity. American Journal of Clinical Nutrition 1994;**59**(5):960-3
16. Weinsier RL. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1995: medical-nutrition education--factors important for developing a successful program. American Journal of Clinical Nutrition 1995;**62**(4):837-40
17. Gershoff SN. National Dairy Council Award for Excellence in Medical/Dental Nutrition Education Lecture, 1996: nutrition education--success or failure? American Journal of Clinical Nutrition 1996;**64**(5):809-12
18. Ball EL, Hughes MR, Leveritt DM. Nutrition in general practice: role and workforce preparation expectations of medical educators. Australian Journal of Primary Health 2010;**16**(4):304-10
19. Mechanic D. Social research in health and the American sociopolitical context: the changing fortunes of medical sociology. Social Science Medicine 1993;**36**(2):95-102
20. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Nutrition training improves health workers' nutrition knowledge and competence to manage child undernutrition: a systematic review. Frontiers in Public Health 2013;**1:**37
21. Mogre V, Scherpbier A, Dornan T, Stevens F, Aryee PA, Cherry MG. A realist review of educational interventions to improve the delivery of nutrition care by doctors and future doctors. Systematic Reviews 2014;**3**:148
22. Wong G, Greenhalgh T, Pawson R. Internet-based medical education: a realist review of what works, for whom and in what circumstances. BMC Medical Education 2010;**10**:12
23. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist synthesis: an introduction: ESRC Research Methods Programme, University of Manchester RMP: Methods Paper 2 2004; ; [http://www.ccsr.ac.uk/methods/ publications/documents/RMPmethods2.pdf].

24. McCormack B, Rycroft-Malone J, DeCorby K, et al. A realist review of interventions and strategies to promote evidence-informed healthcare: a focus on change agency. Implementation Science 2013;**8**:107
25. Pawson R. *Evidence-based policy: A realist perspective*: Sage, 2006.
26. Pawson R, Greenhalgh T, Harvey G, Walshe K. Realist review–a new method of systematic review designed for complex policy interventions. Journal of Health Services Research & Policy 2005;**10**(suppl 1):21-34
27. Westhorp G, Walker B, Rogers P, Overbeeke N, Ball D, Brice G. Enhancing community accountability, empowerment and education outcomes in low and middle-income countries: A realist review: EPPI-Centre, Social Science Research Unit, Institute of Education, University of London: London. 2014
28. Pluye P, Robert E, Cargo M, et al. Proposal: A mixed methods appraisal tool for systematic mixed studies reviews. Montréal: McGill University 2011
29. Yardley S, Cottrell E, Rees E, Protheroe J. Modelling successful primary care for multimorbidity: a realist synthesis of successes and failures in concurrent learning and healthcare delivery. BMC Family Practice 2015;**16**:23
30. Jones AC, Shipman SA, Ogrinc G. Key characteristics of successful quality improvement curricula in physician education: a realist review. BMJ Quality & Safety 2015;**24**(1):77-88
31. Steinert Y, Mann K, Centeno A, et al. A systematic review of faculty development initiatives designed to improve teaching effectiveness in medical education: BEME Guide No. 8. Medical Teacher 2006;**28**(6):497-526
32. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. British Medical Journal 2015;**349**:g7647
33. Maiburg BHJ, Rethans JE, Schuwirth LWT, Mathus-Vliegen LMH, van Ree JW. Controlled trial of effect of computer-based nutrition course on knowledge and practice of general practitioner trainees. American Journal of Clinical Nutrition 2003;**77**(4S):1019S-24
34. Pelto GH, Santos I, Gonçalves H, Victora C, Martines J, Habicht J-P. Nutrition counseling training changes physician behavior and improves caregiver knowledge acquisition. The Journal of Nutrition 2004;**134**(2):357-62
35. Levy J, Harris J, Darby P, Sacks R, Dumanovsky T, Silver L. The primary care nutrition training program: An approach to communication on behavior change. Health Promotion Practice 2011;**12**(5):761-68
36. Carson JAS. Pocket tape measure for waist circumference: Training medical students and residents on a simple assessment of body composition. Journal of Nutrition 2003;**133**(2):547S-49S
37. Taren DL, Thomson CA, Koff NA, et al. Effect of an integrated nutrition curriculum on medical education, student clinical performance, and student perception of medical-nutrition training. American Journal of Clinical Nutrition 2001;**73**(6):1107-1112
38. Buckley KM. Evaluation of classroom-based, Web-enhanced, and Web-based distance learning nutrition courses for undergraduate nursing. Journal of Nursing Education 2003;**42**(8):367-70
39. Ray S, Udumyan R, Rajput-Ray M, et al. Evaluation of a novel nutrition education intervention for medical students from across England. BMJ Open 2012;**2**(1) doi: e000417

10.1136/bmjopen-2011-000417[published Online First: Epub Date]|.
40. Ke L-S, Chiu T-Y, Hu W-Y, Lo S-S. Effects of educational intervention on nurses' knowledge, attitudes, and behavioral intentions toward supplying artificial nutrition and hydration to terminal cancer patients. Supportive Care in Cancer 2008;**16**(11):1265-72

41. Buchowski MS, Plaisted C, Fort J, Zeisel SH. Computer-assisted teaching of nutritional anemias and diabetes to first-year medical students. American Journal of Clinical Nutrition 2002;**75**(1):154-61
42. Puoane T, Sanders D, Ashworth A, Ngumbela M. Training nurses to save lives of malnourished children. Curationis 2006;**29**(1):73-78
43. Hillenbrand KM, Larsen PG. Effect of an educational intervention about breastfeeding on the knowledge, confidence, and behaviors of pediatric resident physicians. Pediatrics 2002;**110**(5):e59
44. Ockene JK, Ockene IS, Quirk ME, et al. Physician training for patient-centered nutrition counseling in a lipid intervention trial. Preventive Medicine: An International Journal Devoted to Practice and Theory 1995;**24**(6):563-70
45. Zaman S, Ashraf RN, Martines J. Training in complementary feeding counselling of healthcare workers and its influence on maternal behaviours and child growth: a cluster-randomized controlled trial in Lahore, Pakistan. Journal of Health, Population, and Nutrition 2008;**26**(2):210-222
46. Eisenberg DM, Miller AM, McManus K, Burgess J, Bernstein AM. Enhancing medical education to address obesity:"See one. Taste one. Cook one. Teach one.". JAMA Internal Medicine 2013;**173**(6):470-72
47. Roche PL, Ciccarelli MR, Gupta SK, Hayes BM, Molleston JP. Multi-School Collaboration to Develop and Test Nutrition Computer Modules for Pediatric Residents. Journal of the American Dietetic Association 2007;**107**(9):1586-89 doi: http://dx.doi.org/10.1016/j.jada.2007.06.008[published Online First: Epub Date]|.
48. Gance-Cleveland B, Sidora-Arcoleo K, Keesing H, Gottesman MM, Brady M. Changes in nurse practitioners' knowledge and behaviors following brief training on the healthy eating and activity together (HEAT) guidelines. Journal of Pediatric Health Care 2009;**23**(4):222-30
49. Ray S, Laur C, Douglas P, et al. Nutrition education and leadership for improved clinical outcomes: training and supporting junior doctors to run 'Nutrition Awareness Weeks' in three NHS hospitals across England. BMC Medical Education 2014;**14**:109
50. Bassichetto KC, Réa MF. Infant and young child feeding counseling: an intervention study. Jornal de Pediatria 2008;**84**(1):75-82
51. Dacey M, Arnstein F, Kennedy MA, Wolfe J, Phillips EM. The impact of lifestyle medicine continuing education on provider knowledge, attitudes, and counseling behaviors. Medical Teacher 2013;**35**(5):e1149-e56
52. Ritenbaugh CK, Thomson CA, Taren D, et al. Nutrition curriculum in medical education: An integrated and comprehensive approach. Teaching and Learning in Medicine 1996;**8**(2):102-10
53. Edwards L, Wyles D. The folic acid message–can training make a difference? Journal of Human Nutrition and Dietetics 1999;**12**(4):317-26
54. Castro MG, Pompilio CE, Horie LM, Verotti CCG, Waitzberg DL. Education program on medical nutrition and length of stay of critically ill patients. Clinical Nutrition 2013;**32**(6):1061-66 doi: http://dx.doi.org/10.1016/j.clnu.2012.11.023[published Online First: Epub Date]|.
55. Kohlmeier M, Althouse L, Stritter F, Zeisel SH. Introducing cancer nutrition to medical students: effectiveness of computer-based instruction. American Journal of Clinical Nutrition 2000;**71**(4):873-77
56. Bjerrum M, Tewes M, Pedersen P. Nurses' self-reported knowledge about and attitude to nutrition–before and after a training programme. Scandinavian Journal of Caring Sciences 2012;**26**(1):81-89

57. Pedersen PU, Tewes M, Bjerrum M. Implementing nutritional guidelines–the effect of systematic training for nurse nutrition practitioners. Scandinavian Journal of Caring Sciences 2012;**26**(1):178-85
58. Conroy MB, Delichatsios HK, Hafler JP, Rigotti NA. Impact of a preventive medicine and nutrition curriculum for medical students. American Journal of Preventive Medicine 2004;**27**(1):77-80 doi: http://dx.doi.org/10.1016/j.amepre.2004.03.009[published Online First: Epub Date]|.
59. Endevelt R, Shahar DR, Henkin Y. Development and implementation of a nutrition education program for medical students: A new challenge. Education for Health: Change in Learning & Practice 2006;**19**(3):321-30
60. de Fine Olivarius N, Palmvig B, Andreasen AH, Thorgersen JT, Hundrup C. An educational model for improving diet counselling in primary care A case study of the creative use of doctors' own diet, their attitudes to it and to nutritional counselling of their patients with diabetes. Patient Education and Counseling 2005;**58**(2):199-202
61. Schlair S, Hanley K, Gillespie C, et al. How medical students' behaviors and attitudes affect the impact of a brief curriculum on nutrition counseling. Journal of Nutrition Education and Behavior 2012;**44**(6):653-57
62. Scolapio JS, Dibaise JK, Schwenk WF, 2nd, Macke ME, Burdette R. Advances and controversies in clinical nutrition: the education outcome of a live continuing medical education course. Nutrition in Clinical Practice 2008;**23**(1):90-95
63. Kennelly S, Kennedy N, Rughoobur G, Slattery CG, Sugrue S. An evaluation of a community dietetics intervention on the management of malnutrition for healthcare professionals. Journal of Human Nutrition and Dietetics 2010;**23**(6):567-74
64. Lewis KO, Frank GR, Nagel R, et al. Pediatric trainees' engagement in the online nutrition curriculum: preliminary results. BMC Medical Education 2014;**14**:190
65. Acuna K, Pires C, Santos G, et al. Detection of nosocomial malnutrition is improved in Amazon region by a standard clinical nutrition education program. Nutricion Hospitalaria 2008;**23**(1):60-67
66. Powell-Tuck J, Summerbell C, Holsgrove G, Garrow J. Four years' experience of an undergraduate medical nutrition course. Journal of the Royal Society of Medicine 1997;**90**(2):67-72
67. Afaghi A, Mohamadi AAHA, Ziaee A, Sarchami R. Effect of an Integrated Case-based Nutrition Curriculum on Medical Education at Qazvin University of Medical Sciences, Iran. . Global Journal of Health Science 2012;**4**(1):112-117
68. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition education. American Journal of Preventive Medicine 2002;**23**(4):296-302
69. Vanderpool C, Lin HC, Scheimann A. NASPGHAN Nutrition University as a Model for Continuing Education Within Pediatric Nutrition. Journal of Pediatric Gastroenterology and Nutrition 2014;**58**(4):469-71
70. Duerksen DR. Teaching medical students the subjective global assessment. Nutrition 2002;**18**(4):313-15 doi: http://dx.doi.org/10.1016/S0899-9007(01)00801-2[published Online First: Epub Date]|.
71. Engel SS, Crandall J, Basch CE, Zybert P, Wylie-Rosett J. Computer-assisted diabetes nutrition education increases knowledge and self-efficacy of medical students. Diabetes Educator 1997;**23**(5):545-49
72. Richards D, Mitchell G. Insight. GPs and nutrition: what they want and how they want it. A GP nutrition education project. Australian Journal of Nutrition & Dietetics 2001;**58**(1):56-59
73. Kipp DE. Technological methods in nutrition education. Developing interactive computerized modules accessible on the World Wide Web for medical students. Topics in Clinical Nutrition 1997;**12**(2):38-44

74. Cooksey K, Kohlmeier M, Plaisted C, Adams K, Zeisel SH. Getting nutrition education into medical schools: a computer-based approach. American Journal of Clinical Nutrition 2000;**72**(3):868S-76S
75. Cheatham M, Boosalis MG, Boissonneault GA. Use of a Computer Tutorial on Nutritional Assessment by Three Different Groups of Health Professions Students. Journal of Allied Health 2002;**31**(4):252-55
76. Kolasa KM, Elesha-Adams M, Patton DD. When a reporter calls: media training to teach nutrition education. Topics in Clinical Nutrition 1996;**11**(4):75-80
77. Fox AL. Evaluation of a Pilot Arts and Health Module In a Graduate Community Nutrition Program. Canadian Journal of Dietetic Practice and Research 2009;**70**(2):81-86 doi: 10.3148/70.2.2009.81[published Online First: Epub Date]|.
78. Ockene JK, Kristeller J, Goldberg R, et al. Increasing the efficacy of physician-delivered smoking interventions. Journal of General Internal Medicine 1991;**6**(1):1-8
79. Bandura A, McClelland DC. Social learning theory. Englewood Cliffs, New Jersey: Prentice-Hall 1977
80. Bandura A. *Self-efficacy: The exercise of control*: Macmillan, 1997.
81. Bandura A. Social cognitive theory: An agentic perspective. Annual Review of Psychology 2001;**52**(1):1-26
82. Westhorp G, Walker B, Rogers P. Under what circumstances does enhancing community accountability and empowerment improve education outcomes, particularly for the poor? A realist synthesis protocol. London: EPPI-Centre. Social Science Research Unit, Institute of Education, University of London 2012
83. Miller GE. The assessment of clinical skills/competence/performance. Academic Medicine 1990;**65**(9):S63-7
84. Carson JAS, Gillham MB, Kirk LM, Reddy ST, Battles JB. Enhancing self-efficacy and patient care with cardiovascular nutrition eduction. American Journal of Preventive Medicine 2002;**23**(4):296-302 doi: http://dx.doi.org/10.1016/S0749-3797(02)00518-4[published Online First: Epub Date]|.
85. Lindgren S, Karle H. Social accountability of medical education: aspects on global accreditation. Medical Teacher 2011;**33**(8):667-72
86. Boelen C, Woollard R. Social accountability: The extra leap to excellence for educational institutions. Medical Teacher 2011;**33**(8):614-19
87. Boelen C, Woollard B. Social accountability and accreditation: a new frontier for educational institutions. Medical Education 2009;**43**(9):887-94
88. Devitt P, Palmer E. Computer-aided learning: an overvalued educational resource? Medical Education 1999;**33**(2):136-39
89. Carr MM, Reznick RK, Brown DH. Comparison of computer-assisted instruction and seminar instruction to acquire psychomotor and cognitive knowledge of epistaxis management. Otolaryngology--Head and Neck Surgery 1999;**121**(4):430-34
90. D'Alessandro DM, Kreiter CD, Erkonen WE, Winter RJ, Knapp HR. Longitudinal follow-up comparison of educational interventions: multimedia textbook, traditional lecture, and printed textbook. Academic Radiology 1997;**4**(11):719-23
91. Deen D, Karp R, Lowell B. A mini-fellowship in clinical nutrition for primary care physicians. Journal of Cancer Education 2000;**15**(3):134-36
92. Heimburger DC, Ullmann DO, Ramsey MJ, et al. Dietary habits of first-year medical students assessed during clinical nutrition course. Nutrition 1994;**10**(3):214-20
93. Hodgson CS, Wilkerson L, Go VLW. Changes in nutrition knowledge among first- and second-year medical students following implementation of an integrated nutrition curriculum. Journal of Cancer Education 2000;**15**(3):144-47

94. Kolasa KM, Jobe AC, Miller MG, Clay MC. Teaching medical students cancer risk reduction nutrition counseling using a multimedia program. FAMILY MEDICINE-KANSAS CITY- 1999;**31**:200-04
95. Edwards M. Nutrition education for medical students: 4th year transition to residency for primary care (1020.3). The FASEB Journal 2014;**28**(1 Supplement):1020.3
96. Carson JAS. *Impact of integrating cardiovascular nutrition in an ambulatory care rotation on the knowledge, attitudes, self-efficacy and patient care practices of fourth year medical students*, 2000.
97. Baker K, Olfert M. Incorporating nutrition education through applied, hands-on culinary elective in medical school training (1020.2). The FASEB Journal 2014;**28**(1 Supplement):1020.2

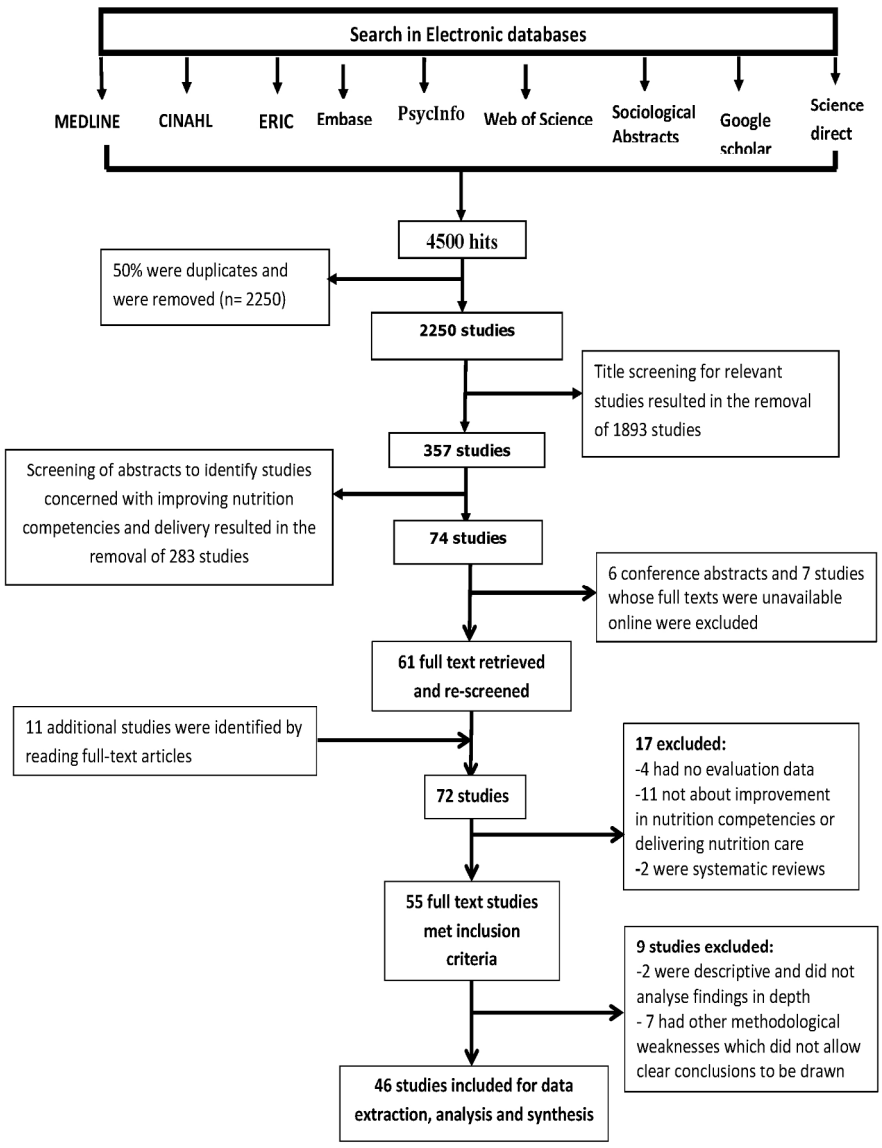


Figure 1: Flow chart of search and selection process

Figure 1: Search and selection process

173x233mm (300 x 300 DPI)

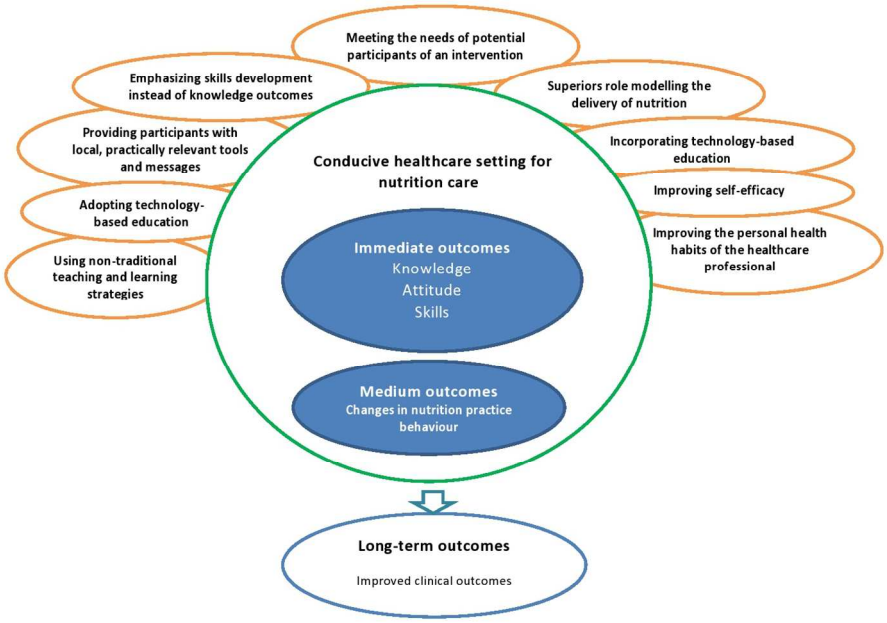


Figure 2: Revised theoretical model or programme theory

Figure 2: Revised thereotical model or programme theory

582x449mm (72 x 72 DPI)

Search strategy used on Ovid Medline

1. effect.mp.

2. evaluation.mp. or Evaluation Studies as Topic/

3. assessment.mp. or Self-Assessment/ or Needs Assessment/

4. analysis.mp.

5. impact.mp.

6. Inservice Training/ or training.mp.

7. intervention.mp.

8. Program Evaluation/ or program*.mp.

9. capacity building.mp. or Capacity Building/ or Research/ or Health Promotion/

10. improve.mp.

11. increase.mp.

12. Nutrition Surveys/ or Nutrition Assessment/ or Nutrition Therapy/ or nutrition.mp.

13. nutrition education.mp. or Health Education/

14. Counseling/ or Weight Loss/ or diet counselling.mp. or Life Style/

15. preventive medicine.mp. or Preventive Medicine/

16. nutrition care.mp.

17. lifestyle modification.mp. or Behavior Therapy/

18. Diet/ or eating behaviours.mp.

19. Patient Education as Topic/ or provision.mp. or "Delivery of Health Care"/

20. delivery.mp.

21. medical students.mp. or Students, Medical/

22. Allied Health Personnel/ or Patient Care Team/ or health professions students.mp. or "Attitude of Health Personnel"/

23. general practitioner.mp. or General Practitioners/

24. primary care physician.mp. or Physicians, Primary Care/

25. Primary Health Care/ or doctors.mp. or Health Knowledge, Attitudes, Practice/

26. 1 or 2 or 3 or 4 or 5

27. 6 or 7 or 8 or 9

28. 10 or 11

29. 19 or 20

30. 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19

31. 21 or 22 or 23 or 24 or 25

32. 26 and 27 and 28 and 29 and 30 and 31

33. limit 32 to (english language and yr="1994 - 2014")

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	2, 4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4, 5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4, 5
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	4, 5
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	NA

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6-28
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	NA
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	NA
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	NA
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	29
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	29
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	29
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: www.prisma-statement.org.