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Systematic Review

Cost-effectiveness of telehealth-delivered nutrition interventions: a systematic review of randomized controlled trials

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Context: *Telehealth-delivered nutrition interventions are effective in practice; however, limited evidence exists regarding their cost-effectiveness.* ***Objective:*** *To evaluate the cost-effectiveness of telehealth-delivered nutrition interventions for improving health outcomes in adults with chronic disease.* ***Data sources:*** *PubMed, CENTRAL, CINAHL, and Embase databases were systematically searched from database inception to November 2021. Included studies were randomized controlled trials delivering a telehealth-delivered diet intervention conducted with adults with a chronic disease and that reported on cost-effectiveness or cost-utility analysis outcomes.* ***Data extraction:*** *All studies were independently screened and extracted, and quality was appraised using the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist.* ***Data analysis:*** *All extracted data were grouped into subcategories according to their telehealth modality and payer perspective, and were analyzed narratively.* ***Results:*** *Twelve randomized controlled trials comprising 5 phone-only interventions, 3 mobile health (mHealth), 2 online, and 1 each using a combination of phone–online or phone–mHealth interventions, were included in this review. mHealth interventions were the most cost-effective intervention in all studies. Across all telehealth interventions and cost analyses from health service perspectives, 60% of studies were cost-effective. From a societal perspective, however, 33% of studies reported that the interventions were cost-effective. Of the 10 studies using cost-utility analyses, 3 were cost saving and more effective, making the intervention dominant, 1 study reported no difference in costs or effectiveness, and the remaining 6 studies reported increased cost and effectiveness, meaning payers must decide whether this falls within an acceptable*

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willingness-to-pay threshold for them. Quality of study reporting varied with between 63% to 92%, with an average of 77% of CHEERS items reported. ***Conclusion:*** *Telehealth-delivered nutrition interventions in chronic disease populations appear to be cost-effective from a health perspective, and particularly mHealth modalities. These findings support telehealth-delivered nutrition care as a clinically beneficial, cost-effective intervention delivery modality.*

INTRODUCTION

Poor nutrition is recognized as the most common modifiable risk factor for chronic disease, resulting in >11 million lives lost and 255 million disability-adjusted life-years in 2017.[1] Nutrition influences the etiology of 7 of the 10 most prevalent chronic diseases globally.[2] Unfortunately, most individuals do not have a diet that adheres to best-practice nutrition guidelines for the prevention of disease,[3] leading to economic consequences that negatively affect healthcare budgets, productivity losses, and societal cost impacts.[4,5]

The Organization for Economic Cooperation and Development projects that global health spending will reach 10.2% of gross domestic product by 2030.[6] There is substantial economic impact from nutrition-related diseases worldwide, and economies often suffer 2-fold when lifestyle factors for preventable disease are not addressed successfully.[7] The annual healthcare burden of poor nutrition ranges from (all values in US dollars [USD] throughout) 1.6 billion in Australia, 5.0 billion in China, 9.5–10.7 billion in the United Kingdom, and up to 50 billion in the United States each year.[8,9] Furthermore, costs related to productivity losses from preventable diseases in a single year ranges between USD 0.4 and 10.5 billion in some countries.[7]

Nutrition care is effective at preventing and improving disease; although it requires investment, it will likely lead to significant economic benefit over time.[3] High-quality evidence also demonstrates that nutrition programs are more cost-effective when delivered by registered dietitians compared with nonqualified nutrition-care professionals.[10] A recent systematic review across Organization for Economic Cooperation and Development countries further verified this, showing face-to-face nutrition care interventions delivered by dietitians in primary care were cost-effective compared with nondietetic care.[3] However, the way nutrition care is delivered has changed substantially, due in part to migration efforts related to the COVID-19 pandemic, which has catalyzed wide-reaching and sweeping reform across the healthcare sector. As a result, health systems, health managers, and clinicians have been challenged to deliver high-quality care using scalable and cost-effective alternatives and hybrid models.[11,12]

Telehealth is defined as the use of information and communication technology to administer and deliver, from a distance, health services by a health professional to a patient.[13] Telehealth-delivered nutrition care is effective for managing chronic disease through better nutrition and clinical outcomes and presents a viable solution to reduce the increasing strain on international health systems.[14]

Telehealth-delivered nutrition care does not increase health spending, according an ecological study of Australian public health–funded nutrition services for chronic disease management.[15] Telehealth-delivered nutrition care is as effective as face-to-face delivery.[16] Hence, telehealth could be a sustainable alternative model of nutrition care if proven to be cost-effective. Law et al[17] recently summarized the cost-effectiveness of lifestyle programs of people living with health-risk factors for any health condition; they found telehealth to be cost-effective in 50% of programs.[17] However, this review was not restricted to chronic disease populations, and the authors reported the cost effects of diet-alone, exercise-alone, and combined programs collectively. Therefore, the effectiveness of telehealth-delivered nutrition care interventions for improving chronic disease management remains unknown. This is a vital knowledge gap for policy and decision-makers considering the evidence-base and economic impact of expanding and sustaining telehealth services for people living with chronic disease and requiring nutrition care. Therefore, the aim of this systematic review was to evaluate the cost-effectiveness of telehealth-delivered nutrition interventions for improving health outcomes in adults with chronic diseases.

METHODS

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guideline (Table S1, Supporting Information online) and the Professional Society for Health Economics and Outcomes Research Criteria for Cost-Effectiveness Review Outcomes

Checklist. A prior systematic review of methodological rigor derived the incremental cost-effectiveness of all diet, exercise, and combined diet and exercise telehealth interventions in populations with any health condition or disease risk factors (PROSPERO registration no. CRD42021224078).[17]

Modifications and amendments to protocol

This systematic review represents an updated search using revised research questions and patient/population, intervention, comparison and outcomes (PICO) criteria, focused on diet-alone and combined diet and exercise interventions for people with chronic diseases only. This systematic review has a much more focused population (those with chronic disease, refined from any population) and intervention (diet interventions, refined from all diet and exercise interventions) than did the previous review, and these are further detailed in the study selection section below. These modifications resulted in 35% of the articles (n = 9 of 24) in the previous review being included in this updated review.

Inclusion criteria

The inclusion criteria for this review are summarized in Table 1.[2] The inclusion criteria included: randomized controlled trials (RCTs), including cluster RCTs and quasi-RCTs; adults with a chronic disease as defined according to the World Health Organization[18]; providing telehealth-delivered nutrition care (with or without exercise) intervention; include a non-telehealth comparator; and reported on cost-effective or cost-utility economic analyses. A non-telehealth comparator was considered usual care, or a control group, which did not receive any form of telehealth-delivered nutrition intervention. Studies that did not meet the above inclusion criteria were excluded, in addition to conference abstracts (where a full version of an article was not available), exercise-only interventions, any study without a usual-care comparator, or raw cost outcomes.

Search strategy and citation screening

A literature search was performed across multiple electronic databases (MEDLINE (PubMed), CENTRAL, CINAHL [via EBSCO], and Embase) from the inception of each database to November 25, 2021, using an updated search based on a search strategy published.[17] This multistep search approach was taken to retrieve relevant trial publications (published in any language) for the present study using forward and backward citation searching and snowballing methods. Screening of non–English-language papers were translated online or via native speaker where required.

Identified citations were exported into Endnote X20 reference management software and deduplicated using the Endnote duplication tool. The title and abstract screening were conducted by 2 independent review authors who screened the titles and abstracts to identify potentially eligible studies using Endnote. Full texts were independently reviewed by 2 review authors. Any discrepancies were resolved by consensus or a third reviewer.

Data collection

Data extraction was completed by 1 review author and checked by a second (J.T.K. and L.L.). Extracted data included study design, author, publication year, country, number of participants, participant characteristics, intervention duration, comparator, health outcome used to derive cost-effectiveness, willingness-to-pay (WTP) thresholds, payer perspectives, and all items of the 2013 Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist, as previously reported.[17] Definitions for the various terms used in data extraction and subsequent interpretation are provided in Table 2. Any discrepancies were resolved by discussion. If any information was missing or unclear, an attempt to contact authors of the study was made through email, with a follow-up email sent after 1 week. If authors did not provide the requested information, the study was excluded.

Quality assessment

The reporting quality was assessed using the 2013 CHEERS checklist[19] criteria and detailed narratively using descriptive statistics. Each article was assigned a value out of 24 points (on the 24-item checklist), with higher values indicating more complete reporting.

Table 1 **PICOS criteria for inclusion of studies**

Population	Adults (aged $\geq$18 y) with a chronic disease as defined by the World Health Organization[18]
Intervention	Telehealth-delivered nutrition care (with or without exercise) intervention
Comparison	Usual care, or a non-telehealth comparison group
Outcomes	Cost-effective or cost-utility economic analyses.
Study designs	Randomized controlled trials, including cluster and quasi–randomized controlled trials

Table 2 **Definitions of key terms**

Cost-utility analysis	A measure of cost and health-related quality of life (QALY) to compare telehealth interventions with usual care. This method is more comparable in a systematic review analysis because it uses a similar effectiveness outcomes (QALY) to determine cost-effectiveness
Cost-effectiveness analysis	A measure of both the costs and a measurable effect (eg, body weight [in kg], diet intake expressed as diet quality points, blood pressure [in mmHg]) from usual care and is presented as a cost per increment of effectiveness. Because of the variety in measured effects, this type of analysis is not easily comparable in a systematic review; there are many different units of effectives used across the included studies.
Health service perspective	Costs incurred by participants in a study that costs the health system money (eg, hospitalizations, primary care visits, clinician time, equipment operating costs and medications)
Societal perspective	Includes costs to a participant, community, or society that are not health-system related and may include (but are not limited to) productivity associated with an illness or a condition, impact on education, travel time, and days taken off work for appointments
Willingness-to-pay threshold	An estimate of what a health decision-maker or funder might be prepared to pay for the observed health benefit (or effectiveness). Typically varies country by country

Abbreviation: QALY, quality-adjusted life-year.

CHEERS items include economic principles such as perspective, time horizon, discounting, effectiveness measurement, and assumptions. Final quality scores were reported as percentages. Studies were scored by 2 reviewers (J.T.K. and L.L.), and a random sample of articles (25%) was cross-checked by another author (K.D.G,) for reporting quality assessment.

Data analysis

Meta-analysis was not performed, due to the heterogeneity of the data across the included studies. Instead, data were analyzed using a combination of narrative analysis and descriptive statistics (numbers and percentages) in Microsoft Excel 2010 (Microsoft, Redmond, WA). Data were organized to be presented using (1) type of telehealth intervention; (2) type of intervention (diet-alone and combined diet and exercise); and (3) the payer perspective used to present the cost-effectiveness results. All costs and price years were adjusted to 2021 USD, using price deflators for gross domestic product and purchasing price parities for gross domestic product.[20]

RESULTS

The electronic search identified 12 975 studies, of which the full text was screened for 419 and 12 met the inclusion criteria (Figure 1). The characteristics of the included studies are presented in Table 3.[21–32] Of the 12 included studies, 5 used phone-only interventions, 3 used mHealth, 2 used online interventions, and 1 each used a combination of phone–online and phone–mHealth interventions. All but 1 of the included studies used within-trial evaluations over a 3–12-month period; and 1 study modelled cost-effectiveness over 10 years.[24] The included chronic diseases were represented in 2 included studies each, including cardiovascular disease,[23,31] hypertension,[27,32] kidney disease,[21,25] obesity,[26,30] osteoarthritis,[28,29] and type 2 diabetes.[22,24]

The diet interventions were all personalized and specific to each chronic disease. One third of the studies (n = 4) delivered diet-only interventions,[21,22,25,32] whereas two-thirds (n = 8) delivered diet and exercise interventions combined.[23,24,26–31] Comparator arms all included usual care. However, 3 studies provided minor information in addition to usual care (but no active intervention),[25,31,32] 1 study used a waitlist usual care,[28] and all other studies' comparator arms were usual-care only. Of the 12 studies, 5 conducted both a cost-effectiveness analysis (CEA) and a cost-utility analysis (CUA), 2 conducted a CEA only, and 5 conducted a CUA only (Table 3).

This meant that there was an equal distribution of CUAs and CEAs reported across the included studies. Both studies measure outcomes in terms of change in cost and change in effectiveness measure between the control and the intervention group. In a CUA, the effectiveness measure is presented in quality-adjusted life-years (QALYs), whereas in CEAs, the effectiveness measure is any quantifiable health outcome. Most contextualized their results as cost-effective or not cost-effective on the basis of their country's specific WTP threshold; however, comparison across the studies using WTP was not suitable, given the diverse thresholds and comparators used. Nine studies reported results from a health-service perspective,[21,22,24,25,27,29–32] 2 reported from a societal perspective,[23,28] and 1 study reported cost-effectiveness results from both payer perspectives.[26]

Cost-effectiveness of the included studies

Payer perspective Figure 2 displays the breakdown of the cost-effectiveness by payer perspective and also according to telehealth method. From a health-service

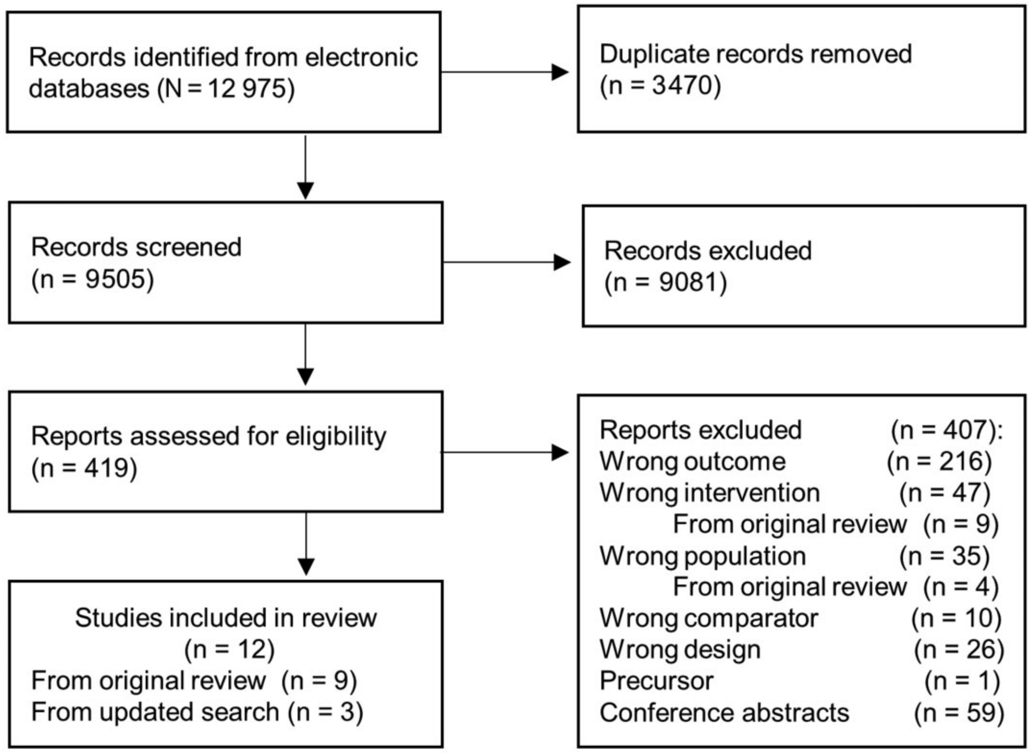

Figure 1 **Flowchart of the search results and included studies.**

perspective, 10 studies reported the results of cost-effectiveness analyses,[21,22,24–27,29–32] showing telehealth was more cost-effective in 60% (n = 6) of the included studies compared with usual care. In comparison, 3 societal perspective studies[23,26,28] suggested the telehealth was cost-effective in one-third (n = 1) of the included studies.

Cost-utility analyses A total of 10 CUAs were reported across the included studies, which reported results as the incremental cost per additional QALY gained.[21,23–26,28,29,31,32] The CUAs were compared by mapping the incremental costs and QALYs on a cost-effectiveness plane, as seen in Figure 3.[21,23–26,28–32] Three studies (30%) were mapped in quartile 2 of the cost-effectiveness plane (Figure 3), indicating dominant interventions that demonstrate both a cost-saving and an increased clinical effectiveness for telehealth-delivered nutrition care compared with usual care. One study reported no clinical benefit and no change in cost.[28] The remaining 6 studies (60%) were in quartile 1 of the cost-effectiveness plane, meaning that telehealth interventions increased clinical effectiveness and increased costs compared with usual care. In these cases, the payer must trade off the gains with costs and determine whether the resultant incremental cost-effectiveness ratio (ICER) meets a suitable WTP threshold to be funded. Of these studies, 1[25] fell within a prespecified WTP, indicating likely cost-effectiveness, where telehealth should be considered for implementation; 1 was unclear and required a high-ceiling WTP threshold[33]; and 3 studies found telehealth costs were higher than prespecified WTP thresholds,[27,30,31] indicating unlikely cost-effectiveness. Among these studies, WTP thresholds ranged from \$8690 to \$118 528 (median \$38 422) (Table 3). The ICERs ranged from cost saving to \$68 205 per QALY gained. Overall, changes in QALYs ranged from no change to an increase of 9.44 QALYs for telehealth interventions (Table 3).

Intervention type The results differed across diet-alone interventions and combined diet and exercise interventions. Four studies of diet-only programs used a health-service perspective. Of these, telehealth was profoundly more cost-effective in 75% (n = 3)[21,22,25] compared with usual care, unclear in 25% (n = 1),[32] and no study was reported as not cost-effective. In comparison, across all payer perspectives, combined diet and exercise programs were cost-effective in 50%[24,27,29] of the included studies and not cost-effective in the other 50%.[26,28,30,31]

Telehealth modality There was heterogeneity in the cost-effectiveness results for telehealth modality used in the included studies (Figure 4). Evidently, all mHealth interventions were shown to be cost-effective according

Table 3 **Characteristics of the included randomized controlled trials**

Reference	Country, perspective, condition	Study population/ sample	Age, mean (SD), y	Telehealth modality	Intervention	Comparator	Health outcome/s	QALYs gained; ICER[a]	WTP[a]	Cost-effectiveness result	Time horizon	QA score, %
Cost-effectiveness analyses[b] and cost utility												
Dawson et al, 2021[21]	Australia, WTEE, health service, hemodialysis	IG = 83 CG = 39	IG = 64.4 (13.2) CG = 65.2 (14.5)	mHealth	Semi-personalized text-message diet-only intervention; content included advice, information, motivation and support to improve kidney dietary behaviors (related to potassium, phosphorus, sodium, fluid), and general healthy eating and lifestyle behaviors.	UC (in-person routine dietary counselling)	QALYs Diet guideline adherence	0.01; −$1418	NR; intervention dominant	Yes; the semi-tailored text message program was both less costly and more effective at 6 mo for improving QALYs and diet adherence compared with the control group	6 mo	88
Kelly et al, 2020[25]	Australia, WTEE, Health Service, stage 3–4 CKD (nondialysis)	IG = 41 CG = 39	IG = 63 (12) CG = 61 (13)	mHealth-phone	Phone diet-only intervention targeting diet quality and adherence to kidney guidelines; in months 0–3, IG received biweekly phone coaching from a dietitian and weekly tailored text messages delivered for the entire program.	UC (in-person care, standard follow-up consultations, and information workbook)	QALYs Diet quality	0.02; −$47.87	NR; Intervention dominant	Yes; the tailored telehealth program was both less costly and more effective at 3 mo for improving diet quality compared with the control group.	3 mo	63
O'Brien, et al, 2018[28]	Australia, WTEE, Society and health service, OA	IG = 59 CG = 60	IG = 63.0 (11.1) CG = 60.2 (13.9)	Phone-only	Phone diet and exercise intervention; IG received brief telephone education and were then referred to NSW Get Healthy Information and Coaching Service for 10 coaching calls.	UC (usual care pathway where participants remained on a waiting list)	QALYs Pain intensity Disability Weight BMI	0; $1197	$77 238	No; referral to a telephone-based weight management and healthy lifestyle service is not cost-effective compared with UC for larger patients with knee OA	6 mo	87
Pell et al, 2022[29]	Netherlands, WTEE, Health Service, OA	IG = 214 CG = 213	IG = 62.1 (7.7) CG = 62.1 (7.0)	mHealth	Mobile app diet–only intervention. Content was fully automated information regarding nutrition and its positive influences on health and OA symptoms. Goals regarding nutrition will target weight management and healthy behavior; the app is augmented with reminders, rewards, and self-monitoring to reinforce app	UC (no active intervention)	QALYs Pain symptoms ADLs Pain	0; −$22	$13 698	Yes; the mobile app was cost-effective compare with UC; costs and QALYs were in favor of the intervention with consideration to the specified WTP threshold	12 mo	88

(continued)

Table 3 **Continued**

Reference	Country, perspective, condition	Study population/ sample	Age, mean (SD), y	Telehealth modality	Intervention	Comparator	Health outcome/s	QALYs gained; ICER[a]	WTP[a]	Cost-effectiveness result	Time horizon	QA score, %
					engagement and health behavior.							
van Keulen et al, 2010[32]	Netherlands, WTEE, Health Service, hypertension	TPC and TMI combined = 408 CG = 409	TPC and TMI = 57.2 (7.1)	Phone-only	Phone diet-only intervention. TMI group received 4 phone calls based on MI on topics like physical activity, fruit and vegetable intake, and fat intake.	UC (no active intervention and 1 information letter after the last follow-up)	Guideline adherence QALYs	0.01; $27	$118 528	Unclear. Phone-only intervention may have been cost-effective compared with UC depending on differing WTP threshold. More research was required on long-term efficacy.	73 wk	75
Cost-effectiveness analyses												
Delahanty et al, 2020[22]	United States, WTEE, Health Service and patient, T2DM	MNT n = 69 In-person n = 70 Telephone n = 72.	MNT = 61.4 (10.7); in-person = 61.3 (10.3); telephone = 62.4 (9.8)	Phone-only	Phone diet-only intervention. IG received a 37-session lifestyle intervention delivered by dietitians.	UC (MNT (delivered in person)	Weight loss	NR (per kg); $1305	$10 673	Yes; the phone diet-only intervention was cost-effective compared with usual care in reducing weight loss, from health system perspective.	12 mo	79
McManus et al, 2021[27]	United Kingdom, WTEE, Society, hypertension	IG = 305 CG = 317	IG = 65.2 (10.3) CG = 66.7 (10.2)	Online	Online self-monitoring diet and exercise intervention. Content covered BP and medication self-monitoring online for first 9 wk. Then, 9 wk after, an optional tool became available outlining user selected lifestyle targets, including healthy eating, physical activity, losing weight, and salt and alcohol reduction.	UC (routine hypertension care with appointments made at the discretion of the practitioner and online access to patient information)	mmHg	NR (per mmHg); $16	$73	Yes; the online intervention was cost-effective compared with UC for reducing BP, achieving a high likelihood of cost-effectiveness at varying WTP thresholds (87%, 93%, and 97% cost effective at thresholds of 20, 30, and 50, respectively)	6 mo	79
Cost utility												
Frederix et al, 2016[23]	Belgium, WTEE, Societal, CAD or CHF	IG = 69 CG = 70	IG = 61 (9) CG = 61 (8)	mHealth	mHealth diet and exercise intervention over 24-wk. Content included internet-based cardiac rehab program, with a motion sensor and associated web service. Emails and text-messages were also used that provided tailored dietary recommendations.	UC (conventional cardiac rehabilitation alone without tele-rehabilitation program)	QALYs	0.03; −$564	NR; intervention dominant	Yes; the addition of tele-rehabilitation to conventional cardiac rehabilitation is cost-effective and more efficient than UC alone when QALYs are considered.	IG = 30 wk; CG = 12 wk	75

(continued)

Table 3 **Continued**

Reference	Country, perspective, condition	Study population/ sample	Age, mean (SD), y	Telehealth modality	Intervention	Comparator	Health outcome/s	QALYs gained; ICER[a]	WTP[a]	Cost-effectiveness result	Time horizon	QA score, %
Graves et al, 2009[24]	Australia, Modelled, Health Service, T2DM	IG = 228 CG = 206	IG and CG = 58.2 (11.8)	Phone-only	Phone diet and exercise intervention. Content included 18 phone calls over 12 mo from trained counsellors aimed at improving diet and physical activity.	UC (management from general practitioner and 3 telephone interviews for the purpose of data collection)	QALYs	9.44; $25 526	$69 518	Yes; telephone counselling is likely to be cost-effective compared with UC when QALYs are considered. There is a need to assess the sustainability of these cost-effectiveness findings.	10 y	79
McConnon et al, 2007[26]	United Kingdom, WTEE, Society, BMI ≥ 30	IG = 111 CG = 110	IG = 48.1 (NR) and CG = 47.4 (NR)	Online	Internet diet and exercise intervention. Content available on a website with personalized diet and exercise advice with minimal professional input.	UC (usual approach to weight loss and printed information at baseline)	QALYs	0.02; $716	$38 422	No; online telehealth intervention was not cost-effective compared with usual care, mainly due to high fixed cost of executing the program.	12 mo	71
Sniehotta et al, 2019[30]	United Kingdom, WTEE, Health Service, BMI ≥ 30	IG = 144 CG = 144	IG = 42.0 (11.6) CG = 41.6 (11.4)	Phone-only	Phone diet and exercise intervention. Content covered lifestyle advice delivered using a combination of a single face-to-face meeting, regular personalized text-messages, and individual phone calls (upon request).	UC (standard lifestyle advice via a newsletter)	QALYs	0.02; $131	$33 382	No; the phone intervention was not likely to be cost-effective compared with UC. The probabilities for the intervention to be cost-effective at standard WTP thresholds of £20 000 to £30 000 per QALY gained was only 34% and 41%, respectively.	12 mo	71
Turkstra et al, 2013[31]	Australia, WTEE, Health Service, CHD	IG = 215 CG = 215	IG = 61.3 (11.3) CG = 59.9 (11.1)	Phone-online	Internet and phone diet and exercise intervention. Content was delivered over 10 phone health coaching sessions from a qualified health professional, who was guided by a web-based application.	UC (standard care with existing written education resources)	QALYs	0.012; $2040	$73 863	No; the phone-online intervention was not cost-effective compared with usual care as there was no significant improvement in QALYs and the intervention significantly increased costs.	12 mo	75

[a]Base rates and currency converted to 2020 US dollars.
[b]ICER per assessed effectiveness outcome.
[c]ICER per QALY.
Abbreviations: ADL, activity of daily living; BMI, body mass index; BP, blood pressure; CAD, coronary artery disease; CEA, cost-effectiveness analysis; CG, control group; CHD, coronary heart disease; CHF, congestive heart failure; CKD, chronic kidney disease; CUA, cost-utility analysis; HRQoL, health-related quality of life; IG, intervention group; MI, motivational interviewing; MNT, medical nutrition therapy; NHMRC, National Health and Medical Research Council; NR, not reported; NSW, New South Wales; OA, osteoarthritis; QA, quality assessment completed per CHEERS; QALY, quality-adjusted life years; RCT, randomized controlled trial; SD, standard deviation; T2DM, type 2 diabetes mellitus; TMI, telephone motivational interviewing; TPC, tailored print communication; UC, usual care; WTEE, within-trial economic evaluation; WTP, willingness to pay; ZonMw, The Netherlands Organization for Health Research and Development.

Figure 2 **Proportional breakdown of the cost-effectiveness according to health service (n = 10) and societal (n = 3) perspectives.**

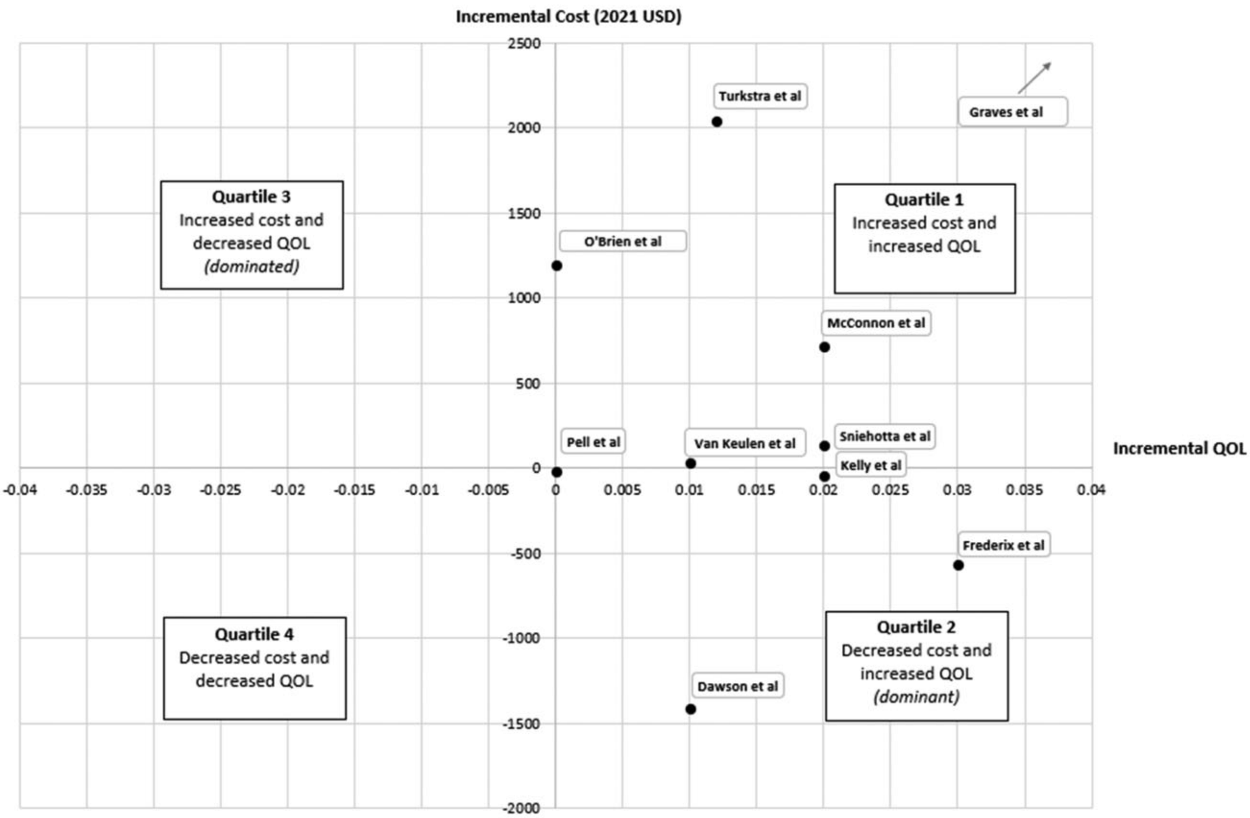

Figure 3 **Cost-effectiveness studies (cost-utility analyses only) mapped on the cost-effectiveness plane with incremental costs and quality-adjusted life-years (n = 10)**. The arrow for Graves et al represents a true point estimate that is beyond the scale of this figure. *Abbreviation*: QOL, quality of living.

to their individually specified WTP,[21,23,25,29] regardless of payer perspective and of whether an intervention was used as a sole intervention strategy or in combination. In contrast, phone interventions were cost-effective 50% of the time, regardless of whether they was used as a sole intervention strategy or in combination. The cost-effectiveness of online health interventions is not clear, with 50% of online-only programs being cost-effective.

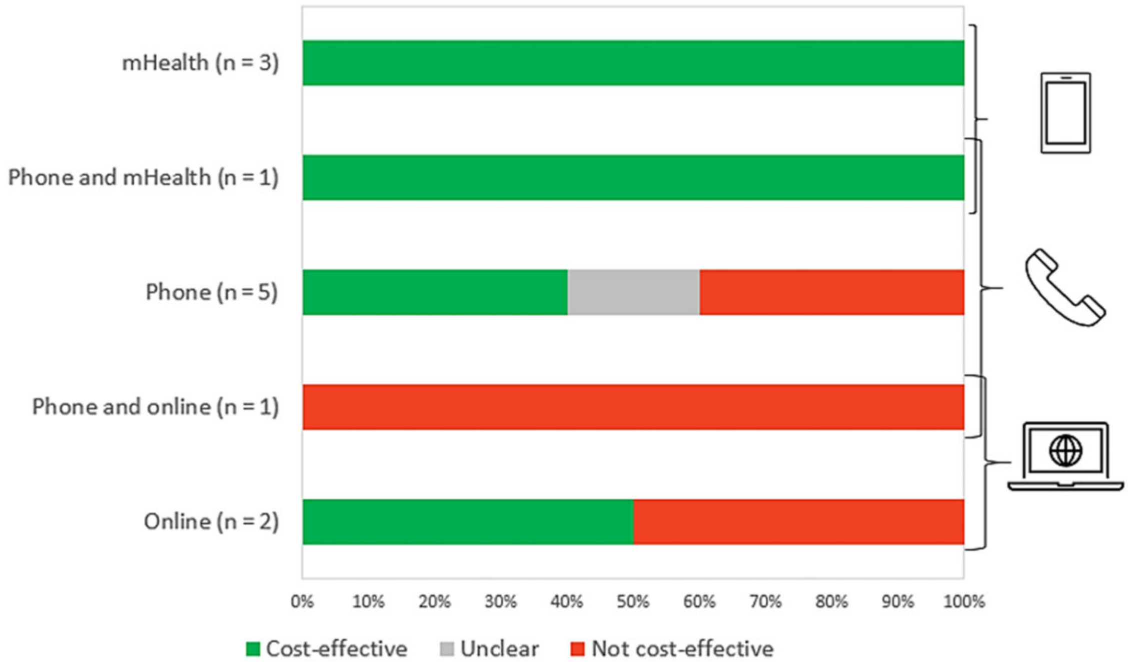

Figure 4 **Cost-effectiveness of all telehealth modalities regardless of payer perspective.**

However, the 1 combined diet and exercise online intervention was not cost-effective (Figure 4).[26]

Quality assessment

A summary of the reporting quality according to the CHEERS assessment results of the 12 included studies is shown in Table 3. The reporting quality across each included study ranged from 63% to 92% out of 24 total items, with an average of 77% of completed items across the included studies. Only 1 study reported discounting[24]; in that study, authors used cost modelling beyond the time horizon of the trial the economic evaluation was conducted. All other studies had a time horizon <12 months and did not report this as the reason why discounting was not applied. Price date, conversions, and underlying assumptions was consistently underreported. The choice of model was also underreported, likely owing to all trials (except 1) being within-trial economic evaluations. There was no difference in study reporting quality observed between telehealth modalities or type of intervention (diet-alone or diet and exercise interventions combined).

DISCUSSION

This systematic review of RCTs aimed to evaluate the cost-effectiveness of telehealth-delivered nutrition interventions for improving health outcomes in adults with chronic disease. The primary finding is that telehealth-delivered nutrition interventions are likely to be cost-effective when measured against country-specific WTP thresholds (reflected in 60% of the included studies). Telehealth appears to be more cost-effective from health service perspectives than from societal perspectives; however, only 3 studies reported on societal perspectives, suggesting more research is required to confirm this. Examining CUAs, which allow programs to be compared (as they compare ICER per QALY gained) showed 40% of programs are cost-effective and 50% require a payer to determine whether the improvement in QALYs is worth the investment (based on individual WTP threshold). The findings of this review can be used to support health policy and for decision support for telehealth-delivered nutrition care as a feasible intervention to deliver evidence-based and high-quality care in a scalable, clinically beneficial, and cost-effective way. This is particularly pertinent given finite budgets to manage the growing incidence and burden of chronic diseases globally.

Integrating patient outcomes from telehealth-delivered nutrition-care interventions with economic evidence is vital to translate data from RCTs into cost-effective measures that improve clinical and/or patient-reported outcomes. It is well known that telehealth-delivered nutrition-care interventions are effective for improving nutrition and health outcomes, compared with usual care and in-person delivery.[14,17] This review now adds compelling evidence for cost-effectiveness of telehealth-delivered nutrition care interventions, particularly for diet-only interventions and those delivered by mHealth modalities.

Investment in nutrition care programs saves healthcare dollars over time. However, the societal value of money is not clear, due to the limited literature reporting this cost perspective and an absence of studies reporting time horizons beyond the completion the RCTs conducted to date. The 3 societal-perspective studies reported time horizons of 12 weeks, 6 months, and 12 months only, whereas it is well-known that telehealth has wide-reaching societal benefits and is commonly cost-effective from this perspective, including productivity and less travel and time away from work.[5] Therefore, time horizons of a RCT are not sufficient for full cost savings to be realized from this perspective, and so analysis should include long-term modelling to demonstrate full benefits.[33] Generally, there are 2 approaches to analyzing cost-effectiveness: within the trial period (alongside trial economic analysis) and extrapolated for the rest of life (modelled economic analysis). In this review, all studies but 1 (the state-transition Markov model of Graves et al[24]) were trial-based evaluations, with a follow-up period ranging from 6 to 24 months. For within-trial evaluations, the costs of telehealth-delivered nutrition-care interventions are incurred during the trial period (eg, equipment, staff resources, internet costs), while the health outcomes and societal economic benefit from such interventions may not be apparent during the trial period due to the long-term impact of nutrition programs. In addition, this ignores the likelihood that chronic diseases, by definition (ie, there is no cure), are conditions whereby the "interventions" theoretically are lifelong and the nature of costs (of healthcare delivery, and the changes in societal costs) are not linear over time. Health systems, interventions, and within-trial economic evaluations are not set up for lifelong interactions, so potentially inaccurate and premature conclusions that such interventions are not good value for money can occur, particularly from a societal perspective (where benefits take time to be realized). Some of these methodological and design challenges can be resolved by extrapolating short-term non–time-to-event outcomes from RCTs over a longer time horizon, albeit this approach has been widely disputed on the basis of statistical uncertainties surrounding the validity of assumptions and lack of universally accepted methodological guidance for extrapolation.

The results of this review add to the growing evidence base that nutrition-care interventions are cost-effective and offer good return on investment. For example, a modelling study in New Zealand demonstrated that every dollar spent on nutrition counselling returns a healthcare savings up to 70.00.[34] Other international investigations have shown strong return on investment to extend to improved health and productivity.[35] In the United States, each funded nutrition consultation for people with diabetes results in 4.7 fewer hospital visits per 100 person-years, with an average cost saving of >6500 total hospital charges.[36] It has been suggested that this return on investment is greater when nutrition care is delivered by registered dietitians,[9] which has more recently been corroborated through international systematic evaluation.[3] Specifically, face-to-face nutrition-care interventions delivered by dietitians in primary care in 8 of the 9 included studies were more costly and more effective than usual care in studies reporting results from within-trial evaluations. Despite these costs, 67% of the included studies reported cost-effectiveness values below the study prespecified WTP threshold.[3] These findings are commensurate with the findings of this review and suggest the cost-effectiveness of nutrition care extends to telehealth models of care. The closest comparison this review has to previously published research is a recently conducted systematic review by Law et al.[17] In their review, Law et al[17] evaluated the cost-effectiveness of telehealth-delivered diet and/or exercise interventions in people living with health conditions (including risk factors in nondiseased populations). This review included 24 diet-alone, exercise-alone, or combined lifestyle interventions and critically summarized the methodological quality and cost-effectiveness of these programs, with 50% reporting cost-effective outcomes and 29% reported as not cost-effective.[17]

Despite the overall cost-effectiveness of telehealth-delivered nutrition care interventions, this review suggests not all telehealth is equally cost-effective. Specifically, results showed that diet-only interventions were potentially more cost-effective than combined diet and exercise interventions. There are several plausible explanations for these findings. First, it is important to remember that cost-effectiveness includes health effectiveness (compared with a control group) and the cost required to achieve this (and whether this is less than the control or whether the high cost falls within a suitable WTP threshold). Therefore, there may be a higher resource demand required to deliver and monitor exercise components of multifactorial interventions in chronic disease. Or, indeed, focusing on diet alone in health delivery programs may better help patients change their behavior and improve health outcomes as a result. Second, concurrent interventions are usually delivered by different health professionals specific to their discipline, and there may be more direct and indirect costs accumulated from these services because of a lack of efficient integration of their delivery in routine practice and research settings. This would present the hypothesis that exercise-only interventions would also be more cost-effective than combined interventions; however, this review cannot address that. In all health states, however, exercise-only programs delivered by telehealth have been reported to be cost-effective in 40% of studies, not cost-effective in 40% of studies, and unclear in 10%; however, most studies agree that telehealth would be a good addition to existing services.[17]

mHealth interventions also were more cost-effective for delivering nutrition care compared with other telehealth modalities (all mHealth studies were cost-effective). The reasons for this likely are diverse, but previous literature has suggested this likely involves improving efficiencies in care, decreasing time to diagnosis, treating people in the home or community compared with in high-cost healthcare facilities, or reducing hospital visits and requiring less clinician time.[37] A systematic review of all mHealth interventions found mHealth to be cost-effective for improving a range of diverse health outcomes in approximately 74% of studies.[38] These findings may have positive implications for future mHealth-delivered nutrition care, including adding support to recommendations for health funders to invest in complimentary mHealth and digital health interventions to support the delivery of nutrition care.[16]

This study has important limitations to consider. First, comparing cost-effectiveness across chronic diseases, telehealth modalities, and different payer perspectives assumes the cost implications, delivery considerations, and health benefits are similar. On the contrary, there are many intricacies specific to each of these sub-components that have been highlighted and, therefore, this cost-effectiveness summary may be too broad. Second, only adult chronic disease populations were included, thus the findings of this review are not generalizable to children. Third, there is uncertainty of cost-effectiveness of combined diet and exercise interventions, and this review did not evaluate the cost-effectiveness of exercise-only interventions in adults with chronic disease. Fourth, the included studies in this review typically excluded the condition of multimorbidities or ignored this in its societal benefit calculations. A critical question to answer remains whether health and societal impacts differ for people with multimorbidities compared with those with a single conditions; multimorbidity is representative of the global population. Fifth, modelled economic evaluations in RCTs were included and dissemination studies, nonrandomized designs, and studies that only modelled costs of an intervention (with no comparison group) were excluded; the results of these analyses may add more understanding to the cost-effectiveness of nutrition interventions. Finally, meta-analysis was unable to be conducted on the results because of the substantial heterogeneity in intervention design and health outcomes used to measure cost-effectiveness (ie, comparing QALYs with weight loss is not appropriate). Measuring impact on health outcomes in a way that is useful for conducting economic evaluations is best done using multi-attribute utility instruments such as the EQ-5D, which can be used to derive QALYs, and this would make results comparable across conditions, delivery modalities, and possibly countries.

Future research could consider alternative approaches to within-trial evaluations and extrapolating non–time-to-event outcomes from RCTs; for example, decision analytical modelling such as simple decision trees or Markov models. Modelled economic evaluation complements trial-based economic evaluations by helping extrapolate beyond the data observed in a trial and makes the findings generalizable to other settings.[39] Such models give analysts the opportunity to simulate disease progression, death, and resource use between intervention and comparator groups over a lifetime or a clinically plausible time. Input parameters for models are often derived from multiple sources of evidence; therefore, decision analytical models are useful in circumstances where heterogeneity in baseline disease states can drive important differences in ICER, with potential implications for clinical and reimbursement decision-making. Early planning in the design of telehealth-delivered nutrition-care programs and trials, with professional health-economist input, is highly recommended for future studies.

CONCLUSION

Telehealth-delivered nutrition-care programs in chronic disease populations appear to be cost-effective from a health-service perspective. mHealth modalities appear to be the most cost-effective telehealth strategy, perhaps because of its relatively low resource cost, its ubiquity, and increasing scalability. The findings of this review support the notion of telehealth-delivered nutrition care as a feasible intervention to deliver evidence-based and high-quality care in a clinically beneficial and cost-effective way. The current body of evidence is highly reliant on within-trial evaluations. Future economic evaluations of telehealth-delivered nutrition-care studies using modelling, whether within-trial or model-based, should consider all patient and health system cost-related factors that inform the decision on economic efficiency of the intervention from all payer perspectives.

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Supporting Information

The following Supporting Information is available through the online version of this article at the publisher's website.

Table S1 **PRISMA 2020 checklist**

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