# Economic Evaluation of Quality Improvement Interventions Targeting Elderly Population in Long-term Care: A Scoping Review

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# Abstract

**Background:** Quality improvement (QI) has received much wider attention in public policy, given the ever-increasing aging population and growing demand of long-term care (LTC). In the policy context, health system planners and administrators need to know the evidence on cost-effectiveness for resource allocation decisions. The objectives of this study were to: identify costs and benefits of the QI strategies in the economic literature; and synthesize the methodological approaches used in the economic studies and reported evidence around the cost-effectiveness of QI strategies in LTC.

**Methods**: A scoping review of three online databases, including PubMed, EconLit, and Google Scholar, was conducted to identify economic studies focusing on elderly population published from September 2010 to August 2020. A combination of search expressions was used to identify the original research articles. Study titles and abstracts were screened, and only full-text articles meeting the inclusion criteria were retained in the review. A standard data extraction template was used capturing patient population, intervention, comparator, the outcome of interest, and study design (PICOS).

**Results:** The search identified 657 records, of which 16 were included in the review. The financial costs were categorized into three groups: (i) developmental, (ii) operational, and (iii) health resource utilization. The terms 'Quality of life,' 'Health-related Quality of Life', and 'Quality of Care' were interchangeably used to express the health outcomes. This study showed mixed results suggesting a substantial variability around cost-effectiveness of QI interventions targeting elderly population in LTC. Almost all studies reported a public payer perspective and a discount rate ranged from 0 to 7%. A poorly defined baseline, the complex nature of the intervention, a lack of appropriate comparator, and varying duration of implementation were key methodological limitations.

**Conclusions:** This review highlights important knowledge gaps regarding societal costs and inconsistencies in reporting of the outcome measures. More research is needed to analyze long-term costs and consequences to better inform decisions on resource allocation in LTC.


# Background

Globally, the ever-increasing aging population – also known as the 'oldest old' phenomenon – is a significant concern for a publicly-funded healthcare system [1]. The United Nations projects a two-fold increase in the number of persons aged 60 and above, leading to approximately 2.1 billion by 2050 [2, 3]. Unlike other health care sectors, services in the long-term care (LTC) focuses on vulnerable populations (i.e. elderly residents with multiple health problems and/or persons with physical or cognitive limitations) who may not be able to advocate on their own behalf [4]. Consequently, the growing demand for LTC and the substantial cost of care for the elderly population highlights a need for quality improvement (QI) in LTC [5].

QI is defined as the systematic and continuous actions that lead to measurable improvement in health care services and the health outcomes of targeted patient groups [6]. QI interventions are often complex, as they combine more than one intervention and the delivery of QI strategies predominantly relies upon diverse health care providers, who may have different training needs and varying attrition rates [7, 8]. In a rapidly changing environment, particularly in the context of LTC, where the workforce turnover is high, there are incremental financial implications to the health system for staff training, skill development, ongoing communication, and support [9]. In Canada, it is estimated that a total of $194 billion investment ($64 billion for construction and $130 billion for operations) is needed to meet the increasing demand of LTC by 2035 [10].

Recently, QI has received much wider attention in LTC, suggesting potential benefits for both care providers, elderly residents and families. A systematic review of studies conducted in North America and Europe revealed that positive organizational and workplace culture were associated with favorable clinical outcomes, such as reductions in hospital-acquired infections, injuries and falls, as well as increased patient satisfaction [11]. In the policy context, it is imperative to understand the efficiency of QI interventions in terms of better patient outcomes and potential cost savings for making decisions about resource allocation [12]. Thus, a comprehensive understanding of costs relative to the benefits of QI intervention(s) is critical to fill the knowledge-gap and guide future economic studies.

The focus of the current review is the exploration of key cost drivers of QI interventions targeting elderly residents in LTC. To assess the cost-effectiveness of QI interventions aiming to promote improved quality of life (QoL) and/or quality of care (QoC) in older adults, our scoping literature review will be addressing the three following research questions:

1. What are the main cost drivers of QI interventions supporting seniors' QoL and/or QoC?
2. What are their health benefits on residents' cognitive and psychological outcomes?
3. What is the evidence on cost-effectiveness of QI interventions?

# Methods

This study utilized a scoping review of the economic literature. The scoping review methodology has been widely used previously, and it is particularly relevant in the area of health economics for emergent or urgent policy considerations [13, 14]. The publications were retrieved from three online databases including PubMed, EconLit, and Google Scholar. Studies were considered eligible for review if they met the following inclusion criteria: (i) reported on costs and benefits related to QI strategies, (ii) targeted elderly population in the LTC setting, (iii) full-text articles available in the English language; and (iv) published from September 2010 to August 2020. The exclusion criteria were defined as (i) non-economic studies; (ii) non-research articles (e.g. commentaries, blogs/posts); and (iii) conference abstracts and study protocols.

### Screening and study selection

A combination of search expressions, for example: ((cost-effectiveness) AND (long-term care) (AND quality improvement); OR (cost-benefit) AND (long-term care) AND (quality improvement)) were used to identify original research articles. Applying these search expressions produced a list of publications for the title and abstract screening. Duplicate publications were identified and removed. The full-text articles meeting the inclusion criteria were retained in the review.

### Data extraction

A standard data extraction template was used to record patient population, intervention, comparator, the outcome of interest, and study design (PICOS) [15]. This review also reports on methodological approaches pertinent to the economic analysis such as the source of cost/outcome parameters, the choice of the model, the perspective adopted, discounting, time horizon, and methods for dealing with uncertainties. The summary table lists studies in chronological order according to the publication year.

### Data synthesis

The emerging evidence around financial costs of QI strategies was categorized into broad buckets and cost ingredients were summarized. The benefits (i.e., health improvements and/or cost avoidance) attributable to QI work were described. The methodological approaches and key study limitations were narratively synthesized.

# Results

The search strategy revealed 657 references from the following sources: PubMed (n = 345), EconLit (n = 14), and Google Scholar (n = 298). Fifty-one duplicate references were removed. Of the remaining 606 references, 581 were removed because they did not focus on QI (n = 392), were not conducted in LTC settings (n = 141) and not economic studies (n = 48). Based on a full-text screening, nine references were removed (conference abstracts, n = 4 and study protocols, n = 5). Sixteen references were included in this review, of which 13 were economic evaluation studies and three were systematic reviews (Figure 1).

### Summary of the included studies

There were 13 individual economic studies and three systematic reviews. These studies originated from Canada (n = 3), United States (n = 2), United Kingdom (n = 2), Australia (n = 2) and the Netherlands (n = 2), along with one study each from Spain and Germany. The study topics represented a wide range of QI strategies such as pharmacist-led medication reviews [16-19], peer coaching for safe resident handling [20-21], preventive practices for reducing falls [22-23], preventing pressure ulcers [24-26], infection prevention [27-28], and dealing with challenging behaviors [29-30]. Several studies involved a multidisciplinary team, comprised of geriatricians, pharmacists, psychologists, registered nurses, licensed practical nurses, recreational therapists and care-aides working in the LTC settings. Most of these studies were published in the last five years (n = 11). Only 2 studies were published in the health economics-related journals, whereas other studies were published either in geriatric medicine or clinical medicine journals. Table 1 summarizes the included studies.

### Methodological approaches

Table 2 lists methodological approaches in the included studies. The economic studies represented a wide range of methodological approaches such as trial-based economic evaluations (n = 5), cost-effectiveness studies (CEA) (n = 5), cost-benefit studies (n = 2) and a cost-minimization study (n = 1). A vast majority of the studies included analyzed primary data (n = 9), while a few studies reported on a retrospective analysis of the secondary data (n = 4) and systematic reviews (n = 3). Almost all studies examined financial costs relative to the health benefits of QI strategies using a public-payer (i.e., health care system) perspective. Because many studies evaluated QI projects over a short-time horizon, incremental costs and outcomes were reported for $\leq$ 2 years. Only two studies applied a Markov-chain model to

calculate long-term, 20 years or lifetime, costs and outcomes of QI strategies [24-25]. Studies originating from Canada used a discounting rate of 3 to 5% [21,24,26], as compared to 7% in other studies originating from the United States [20], and Germany [23]. The uncertainties in the model input parameters of costs and outcome were addressed by one-way deterministic sensitivity analysis [18,20-22,26,28], nonparametric bootstrapping [17], and probabilistic sensitivity analysis [16,23-25]. Only two studies reported on a budget impact analysis [23,26].

### Financial costs of QI interventions

The cost inputs were derived from multiple sources including health insurance providers, national/provincial administrative databases, LTC facility records and costing exercises embedded alongside the trial. The financial costs were categorized into three broad-buckets: (i) developmental, (ii) project/program implementation, and (iii) health care. The developmental costs, often one-time expense, represented planning activities such as, initial consultation [18], focus groups [21], and training [18,29]. The project/program implementation included costs of equipment, maintenance [18,20,24,28,30], educational package [23,29], printing and supplies [16,21,26]. The health care costs comprised of administrative staff and care-providers' salaries in the LTC facilities [18,23-24,26], transfers to hospitals [22], in-patient hospitalization [16,18,22,23], out-patient-and-ambulatory visits including day-surgeries/procedures [16,18,22-23,25], medical supplies and medications [16,23,28]. Only two studies reported on the societal costs (i.e., costs to the health system, as well as out-of-pocket costs and productivity losses) [21,29]. (Table 3)

### Health outcomes/benefits of QI interventions

The literature revealed a combination of the economic and clinical outcome variables relevant to QI intervention. The terms 'Quality of life' (QoL), 'Health-related Quality of Life' (HRQoL) and 'Quality of Care' (QoC) were used interchangeably to express health gains. Studies conducted by Jódar-Sánchez [17], and Twigg et al. [18] administered a validated tool (i.e. EuroQol EQ-5D-5L) to measure HRQoL – mainly quality-adjusted life years (QALYs) – in elderly residents undergoing pharmacist-led medication reviews. Other studies extracted disease-specific QALY estimates from previously published literature [23-25]. The QoC variables included infection prevention [27], falls or injury prevention [16,21-23], reducing the length of hospital stay [24], and avoiding hospital readmissions [22]. Some studies also reported other outcomes specific to a medical condition or disease such as cognitive improvements [18], reductions in the disease incidence or prevalence [25], preventing mortality [23-24], and reducing agitation-level [29-30]. Overall, the economic outcomes were presented as the incremental cost relative to benefit [16-18,22-25,29-30], net monetary benefit [20-21], and cost savings [19,26,28] or cost avoidance [4,26-27].

### Cost-effectiveness of QI interventions

Zwijsen et al., [29] performed a trial-based CEA of GRIP- a challenging behaviour care program based on the recent guideline-driven educational package for managing elderly residents diagnosed with dementia, as compared with standard care in the Netherlands setting. The findings showed that implementation of the GRIP program was more costly than usual care (i.e., mean cost difference € 276; and 95% CI: €237 to €349), and there was a very small difference in the QALYs (i.e., -0.02; 95% CI: -0.06 to -0.003) between two groups. Another economic study from Spain evaluated the cost-effectiveness of a pharmacotherapy follow-up using a prospective observational research design [17]. In the base-case analysis, the pharmacotherapy follow-up was found more costly (crude unadjusted incremental cost, €399) and less effective (incremental QALYs, -0.001) as compared with usual care. However, the incremental cost-effectiveness ratios (ICERs) appeared more favorable (ranged from €3,898.69 to €6,573.56 per QALY gain, and the probability of pharmacotherapy follow-up being cost-effective was 76-78% at a willingness-to-pay (WTP) threshold of €30,000 per QALY) when both costs and utility scores were adjusted in the subsequent scenario-based analysis. A cost-benefit analysis conducted by Lahiri et al., [20] reported cost savings of implementing a safe resident handling program in the United States (US). This study also showed mixed results suggesting a substantial variability in net savings across LTC facilities. Of 110 facilities, 61 (55.5%) had a positive net savings of approximately US$3,064 per bed, and negative savings (i.e., the incremental cost of US$992 per bed) in the remaining 49 facilities. Stern A et al., [24] also showed an incremental cost of CA$731 and incremental QALYs of 0.03 (ICER: CA$7,824,747 per QALY gained) for the oral nutrition supplements in high-risk residents with recent weight loss. Additionally, the prevention strategy of skin emollient for high-risk residents with dry skin yielded an ICER of CA$78,286 per QALY gained. Since the ICERs were above the standard acceptable WTP threshold of CA$50,000 per QALY, both prevention strategies were not considered cost-effective.

Other studies demonstrated favorable ICERs (i.e., lower incremental cost relative to benefit). In a trial-based economic evaluation of the pharmacist-led reviews of psychoactive medications (specifically antipsychotics, hypnotics, and anxiolytics) as compared with usual care in the United Kingdom [16], the proportion of nursing home residents receiving inappropriate psychoactive drugs were 19.5% and 50.4% in the intervention and control groups, respectively. The average cost of health resource utilization was relatively lower ($4,923 per resident per year, 95% CI: $4,206 – $5,640) in the intervention group, as compared to $5,053 per resident, per year (95% CI: 4,328 - $5,779) in the control

group. In this study, the ICER was estimated at – 422 (i.e., incremental cost per proportion of resident receiving one or more inappropriate psychoactive drugs). Hewitt et al., [22] found an ICER of AU$18, per fall avoided; 95% CI: - $380.34 to $417.85 for a strength and balance exercise program (SUNBEAM), as compared to usual care in a randomized control trial in Australia. In a study conducted by Muller et al. [23], the multifactorial fracture prevention program implemented by a multidisciplinary team was also found highly cost-effective, as compared to no prevention. This study showed the incremental cost of €119 and incremental QALYs of 0.006 (ICER: €21,353 per QALY gained), yielding a probability of cost-effectiveness of 90% at a WTP of €36,000 per QALY).

## Discussion

It is crucial for health policymakers and/or stakeholders, including local health authorities and site-level administrators, to have an understanding of the economic impact and evidence around value for money in applying QI interventions in LTC. Our findings demonstrated a wide range of cost variables that could easily be classified into three main groups: developmental, operational / implementation and health care. Because the majority of economic studies used a public-payer perspective, patient-level out-of-pocket costs including time/productivity losses were not considered necessary in the economic analysis. This review identified a combination of QoL and QoC indicators representing health outcomes. Many economic studies extracted QALY estimates from previously published literature, as administering a validated tool to measure HRQoL could be a resource-intensive exercise. Also, some studies evaluated clinical outcomes over a short time period, in which case a HRQoL assessment was not required. Thus, more emphasis was given to QoC indicators such as falls or injuries prevented, pressure ulcer risk-reduction and hospitalization avoided.

Conventionally, the impact of QI interventions targeting behaviour change communication cannot be assessed over a short-term, thus a multi-year study or subsequent follow-ups at different time periods are required [31]. In this review, we found only two economic studies that analyzed long-term costs and health outcomes [23-24]. Modeling costs and benefits over a lifetime provides a fulsome view of the return on investment in the long run, which is an important element of allocating scarce resources in healthcare. In a study conducted by Zwijsen et al., [29], authors reported that increased physicians' and psychologists' time on the unit was the main cost driver making QI intervention more costly than standard care. In order to address the uncertainties associated with long-term costs, statistical regression methods are widely used in the economic analysis of QI interventions [32]. In our review Jódar-Sánchez et al. showed a much higher probability of pharmacotherapy being cost-effective when both costs and QALYs were adjusted for age, sex, health problems, and use of herbs and medications [17].

This review highlights potential issues in terms of interpreting the cost-effectiveness findings, as reported in the economic studies. Studies conducted by Jódar-Sánchez et al., [17] Lahiri et al.,20 Stern A et al., [24] and Zwijsen et al., [29] found higher costs relative to benefits (or even negative benefits) of QI strategies, as compared with standard care. Such unfavorable (i.e., not cost-effective) findings were largely explained by either a small effect size (i.e., negligible QALYs gain) as demonstrated by Stern A et. Al., [24] or by detrimental effect (i.e., QALY loss) as reported by Zwijsen et al., [29]. It is, however, difficult to explain why some strategies, albeit non-harmful at face value, resulted in negative QALYs. The literature revealed that QI initiatives are typically piggy-backed with other services that introduce the possibility of a 'confounding effect' or 'effect-dilution' further making it difficult to estimate a robust effect-size attributable to a QI intervention. Also, poorly defined baseline, lack of appropriate comparator and varying duration of implementation may underestimate the benefit of QI strategies. Further research is needed to understand and explore the innovative ways of addressing methodological challenges in the economic analysis of QI initiatives.

Given the rising cost of care and inconsistent practices improving the QoL in an aging population, the findings of our study are of importance to health system planners in LTC. To the best of our knowledge, this is the first review of the emerging costs, benefits of QI in LTC and methodological approaches used in published economic literature. This review captured economic studies published in last ten years, however there is a possibility of missing information published before or after this period. In this review, only English-language references were examined, so articles appearing in other languages were omitted.

## Conclusion

We presented a scoping review of costs, benefits and cost-effectiveness of various QI interventions targeting on elderly population in LTC. The economic literature on QI in LTC is scarce and highlight important knowledge gaps regarding societal costs. Although QALY is a widely accepted outcome measure in the economic analysis, some studies reported surrogate outcomes which makes cross-comparison of QI strategies difficult and prohibits the meta-analysis of published costs and outcome parameters in future studies. There is mixed evidence around the economic impact of QI strategies and more research is needed to analyze long-term costs and consequences to better inform

decisions on resource allocation in LTC. Overall, the methodological approaches and key limitations identified in this review provides valuable directions for future economic studies evaluating value for money of QI interventions elsewhere.

# Declarations


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## Authors' contributions

AK, CK and CM conceived the idea of the study. AK designed the data extraction, undertook the review and wrote the first draft of the manuscript. All authors contributed to subsequent redrafting of the manuscript and approved the final version.


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## Availability of data and materials

## All data and materials are listed in the article.

### Ethics approval and consent to participate

## This review was conducted as part of a large economic study of a province-wide quality improvement initiative in British Columbia, Canada. This study was approved by the IRB of the University of British Columbia (certificate #: H18-03581).

## Consent for publication

## Not applicable

## Competing interests

The author(s) declare that they have no competing interests.

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## Tables

**Table 1.** Population, intervention, comparator, outcome and study design (PICOS)

| Publication, year | Population (P) | Intervention (I) | Comparator (C) | Outcome (O) | Study design (S) |
|---|---|---|---|---|---|
| Hewitt J et al. 2019 [22] | Residents identified with mix of high and low care needs. | Strength and balance exercise program | No intervention | Mean cost per fall, and incremental cost per falls avoided. | Trial-based economic evaluation |
| Twigg et al. 2019 [18] | Residents diagnosed with cardiovascular disease or diabetes and prescribed one or more medicines | Medication review and person-centered consultation | Status quo | Clinical outcomes, and incremental cost per quality-adjusted life years (QALY) gained | Cost-effectiveness analysis |
| Adeyemi A et al. 2018 [28] | Residents enrolled in wound management program | Single-use negative pressure wound therapy (sNPWT) | Traditional negative pressure wound therapy (tNPWT) | Monetary gain (i.e., cost savings) by using the sNPWT. | Cost-minimization analysis |
| Mervin MC et al. 2018 [30] | Residents diagnosed with dementia | PARO, a therapeutic robotic seal. | Plush toy and usual care | Incremental cost per Cohen-Mansfield Agitation Inventory scale averted relative to usual care. | Trial-based economic evaluation |
| Hasan S et al. 2017 [19] | Residents in the long-term care | Pharmacist-led medication review | NR | Improved clinical outcomes, and cost savings | Systematic review |
| Cohen C et al. 2016 [27] | Residents and staff in the long-term care | Infection prevention practices | NR | Cost of infection prevention. | Systematic review |
| Tompa E et al. 2016 [21] | Full-time equivalents of nursing staff | Peer coaching for overhead lift use | Status quo | Reduction in the injury rate, lost-time injury claims averted, and net monetary gains. | Cost-benefit analysis |
| Easton T et al. 2016 [1] | Residents in the long-term care | Workforce structure and care processes | NR | Return on investment (i.e., monetary savings) from societal perspective. | Systematic review |
| Zwijsen SA et al. 2016 [29] | Residents diagnosed with dementia | Grip on challenging behavior care program | Status quo | Improvement in the quality of life outcomes, and incremental cost per QALY gained. | Trial-based economic evaluation |
| Muller D et al. 2015 [23] | Residents with recent admission in the nursing home | Fall prevention program | NA | Rate of falls, costs associated with fall events, and incremental cost per QALY gained. | Cost-effectiveness analysis |
| Jódar-Sánchez F et al. 2014 [17] | Residents who were cognitively intact | Pharmacist-led pharmacotherapy follow-up in collaboration with the resident and the general practitioner | Status quo | Incremental cost per QALY gained. | Cost-effectiveness analysis |
| Paulden M et al. 2014 [26] | Residents identified with mobility limitations | Turning for ulcer reduction (repositioning in 3-hour or 4-hour intervals) | Repositioning in 2-hour intervals | Cost savings per day, and total economic benefit at the province level. | Trial-based economic evaluation |
| Lahiri S et al. 2013 [20] | Nursing home employees | Safe resident handling program | Status quo | Workers' compensation, cost of turnover, and net monetary savings. | Cost-benefit analysis |
| Stern A et al. 2011 [24] | Residents at risk of a stage 2 to 4 pressure ucler | Strategies for preventing pressure ulcer | Compared multiple strategies | Cost of quality improvement strategies, and incremental cost per QALY gained. | Cost-effectiveness analysis |

| Publication, year | Population (P) | Intervention (I) | Comparator (C) | Outcome (O) | Study design (S) |
|---|---|---|---|---|---|
| Patternson et al. 2011 [16] | Residents who had full resource use data available at 12 months | Pharmacist-led clinical and prescribing review for psychoactive medications | Status quo | Proportion of residents receiving inappropriate psychoactive medication at 12 months, and rate of falls, cost of healthcare resources used per resident per year. | Trial-based economic evaluation |
| Makai P et al. 2010 [25] | Multidisciplinary team (medical, paramedical staff) | Activities for preventing pressure ulcer | NA (pre-post design) | Rate of incidence and prevalence for pressure ulcer, and Incremental cost per QALY gained. | Cost-effectiveness analysis |

*Abbreviations: Interactive robotic seal (PARO), Quality adjusted life years (QALYs), single-use Negative Pressure Wound Therapy (sNPWT), traditional Negative Pressure Wound Therapy (tNPWT), Not available (NA), Not reported (NR)*

**Table 2.** Methodological approaches

| Publication, year | Source data | Modeling technique | Perspective | Discounting | Time horizon | Method of dealing uncertainty | Economic outcome | Budget impact analysis |
|---|---|---|---|---|---|---|---|---|
| Hewitt J et al. 2019 [22] | Primary data from the trial | Trial-based economic analysis | Health Services (Australia) | 0% | 1 year | One-way deterministic sensitivity analysis | Mean cost per fall, and incremental cost per falls avoided. | NR |
| Twigg MJ et al. 2019 [18] | Primary data from the project | Pre-post cost effectiveness analysis | National Health Services (United Kingdom) | 0% | 1 year | One-way deterministic sensitivity analysis | Incremental cost per QALY gained. | NR |
| Adeyemi A et al. 2018 [28] | Retrospective data from electronic wound management program | Cost-minimization analysis | Institution (United States) | 0% | <1 year | One-way deterministic sensitivity analysis | Monetary gain (i.e., cost savings) by using the sNPWT. | NR |
| Mervin MC et al. 2018 [30] | Primary data from a cluster-randomized trial | Trial-based cost-effectiveness analysis | Health Services (Australia) | 0% | < 1year | NR | Incremental cost per Cohen-Mansfield Agitation Inventory scale averted relative to usual care. | NR |
| Tompa E et al. 2016 [21] | Primary data from 15 long-term care facilities | Cost-benefit analysis | Health services (Canada) | 3% | 5 years | One-way deterministic sensitivity analysis | Cost per injury claims averted, and net monetary gains | NA |
| Zwijsen SA et al. 2016 [29] | Primary data from the trial | Trial-based cost-effectiveness analysis | Societal perspective (Dutch) | 0% | 1 year | NR | Incremental cost per QALY gained. | NR |
| Muller D et al. 2015 [23] | Retrospective data from literature and public data base | Markov based simulation | Health Insurance (Germany) | 7% | 20 years | Both deterministic and probabilistic sensitivity analysis | Costs associated with fall events, and incremental cost per QALY gained. | Yes |
| Jódar-Sánchez F et al. 2014 [19] | Primary data from the project | Cost-utility analysis | Selected care homes (program-level) | 0% | 1 year | Non-parametric bootstrapping | Incremental cost per QALY gained. | NR |
| **Publication, year** | **Source data** | **Modeling technique** | **Perspective** | **Discounting** | **Time horizon** | **Method of dealing uncertainty** | **Economic outcome** | **Budget impact analysis** |
| Paulden M et al. 2014 [26] | Primary data from nursing homes | Cost minimization analysis | Ministry of Health (Ontario Canada) | 5% | <1 year and 2 years | One-way deterministic sensitivity analysis | Cost savings per day, and total economic benefit at the province level. | Yes |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Lahiri et al. 2013 [20] | Retrospective data from privately run insurance corporation | Cost-benefit analysis | Health care employer (United States) | 7% | 8 years | One-way deterministic sensitivity analysis | Average net savings, and avoided turnover costs | NA |
| Stern A et al. 2011 [24] | Primary data from surveys, and retrospective data from literature and administrative database | Markov model | Health system / Public payer (Canada) | 3% | Lifetime | Probabilistic sensitivity analysis | Cost of quality improvement strategies, and incremental cost per QALY gained. | NR |
| Patternson et al. 2011 [16] | Primary data from a cluster-randomized trial | Trial-based cost-effectiveness analysis | National Health Services (United Kingdom) | 0% | 1 year | Multi-way deterministic sensitivity analysis | Incremental cost per resident per year. | NR |
| Makai P et al. 2010 [25] | Retrospective data from the project | Markov model | Healthcare (Dutch) | 4% costs; and 1.5% for effectiveness | 2 years | Probabilistic sensitivity analysis | Incremental cost per QALY gained. | NR |

*Abbreviations: Quality adjusted life years (QALYs), single-use Negative Pressure Wound Therapy (sNPWT), traditional Negative Pressure Wound Therapy (tNPWT), NA (Not applicable), Not reported (NR)*

**Table 3**. Costs- ingredients and buckets reported in economic studies

| Publication, year | Cost ingredients | Cost buckets* | Currency, price year |
|---|---|---|---|
| Hewitt, 2019 [22] | Cost of project/activities officer, and healthcare personnel costs: medical practitioner, registered nurse, and physiotherapist | Project / program implementation | Australian dollar (AUD), 2015 |
| | Ambulance costs, cost of hospitalization for acute care without fracture, cost of hospitalization due to fracture, and same-day hospital visit costs | Health care | |
| Twigg, 2019 [18] | One-time training costs, and initial consultation costs | Developmental | British pound (£GBP), 2014/15 |
| | Interim review costs, 6 monthly review costs, and cost of equipment: cholesterol testing kit, blood pressure monitoring devices, weight and height measuring scales | Project / program implementation | |
| | Healthcare providers' cost (pharmacist, health care assistants, general practitioners), in-patient hospital admission costs, cost of out-patient visit and practice nurse visit | Health care | |
| Adeyemi, 2018 [28] | Cost of medical equipment and procedures: traditional negative pressure wound therapy (NPWT), and single-use NPWT, and medication costs | Health care | United States dollar (USD), 2016 |
| Mervin, 2018 [30] | Equipment costs (for example: robotic seal, battery, accessories), within trial cost of maintenance, cleaning costs, and cost of medications | Project / program implementation | Australian dollar (AUD), 2017 |
| Tompa, 2016 [21] | Cost of focus groups with staff including registered nurses, license practitioner nurses, and care aides | Developmental | Canadian dollar, (CAD), 2006 |
| | Coach training and/or refresher sessions costs, workers time spent receiving training, other operational expenses: stationary, supplies, printing, sustenance during training, and coach scrubs, cost of travel and accommodation to training site | Project / program implementation | |
| | Costs per injury claim: worker out-of-pocket, productivity losses, administrative and insurer costs | Health care and individual-level costs (Societal) | |
| Zwijsen, 2016 [29] | Cost of initial trainings | Developmental | Netherlands euro (€), 2006 |
| | Cost of educational package, healthcare personnel costs: nursing staff, recreational therapist, psychologists, and elderly care physician | Project / program implementation | |
| | Psychoactive drug costs, and cost of sick leave | Health care and individual-level costs (Societal) | |
| Muller, 2015 [23] | Group education and written information costs, hip protector costs, labour costs for education, cost of environmental check, cost of group exercise over 6 months | Project / program implementation | German euro (€), 2012 |
| | Cost of geriatric assessment by general practitioner, hospitalization costs for hip fracture in year 1, year 2, and year 3+, cost of upper limb fracture, medication costs, and cost of ambulatory services (physiotherapy, and ergotherapy) | Health care | |
| Jódar-Sánchez, 2014 [17] | Cost of pharmacist- led interventions and prescribed medications costs | Project / program implementation | Spanish euro (€), 2013 |
| Paulden, 2014 [26] | Supplies costs: washcloths, briefs, skin cream, and barrier cream | Project / program implementation | Canadian dollar, (CAD), 2012 |
| | Cost of nursing staff, physician services costs, and cost of ambulatory visits or procedures including day surgery | Health care | |
| Lahiri, 2013 [20] | Cost of equipment and labor | Project / program implementation | United States dollar (USD), 2006 |
| | Medical care and indemnity costs, productivity losses, group health and disability insurance premiums, cost of malpractice litigation, and employee turnover costs | Health care | |

| Publication, year | Cost ingredients | Cost buckets* | Currency, price year |
|---|---|---|---|
| Patterson, 2011 [16] | Costs of monthly pharmacist-led medication reviews, and consultation with other health professionals, and compensation for administrative staff. Other overhead costs including travel and office supplies | Project / program implementation | United States dollar (USD), 2005 |
| | Cost of prescribed medication, visits to healthcare professionals, general practitioners' services, in-patient hospitalization, laboratory and tests | Health care | |
| Stern, 2011 [24] | Material and equipment costs: pressure redistribution foam mattresses, cost of oral nutrition supplements, cost of skin moisturizer, and foam cleanser costs | Project / program implementation | Canadian dollar, (CAD), 2009 |
| | Nursing care costs, and other long-term care costs: programming, food and accommodation | Health care | |
| Makai, 2010 [25] | Cost of material, program support, knowledge management, and training of project staff: caregiver, specialists | Project / program implementation | Netherlands euro (€), 2006 |
| | Cost of measurements and/or assessment, and medical procedure costs: smearing the skin with topical agents, and inserting a catheter | Health care | |

* *Categorized into broader buckets based on the description of cost variables*

## Figures

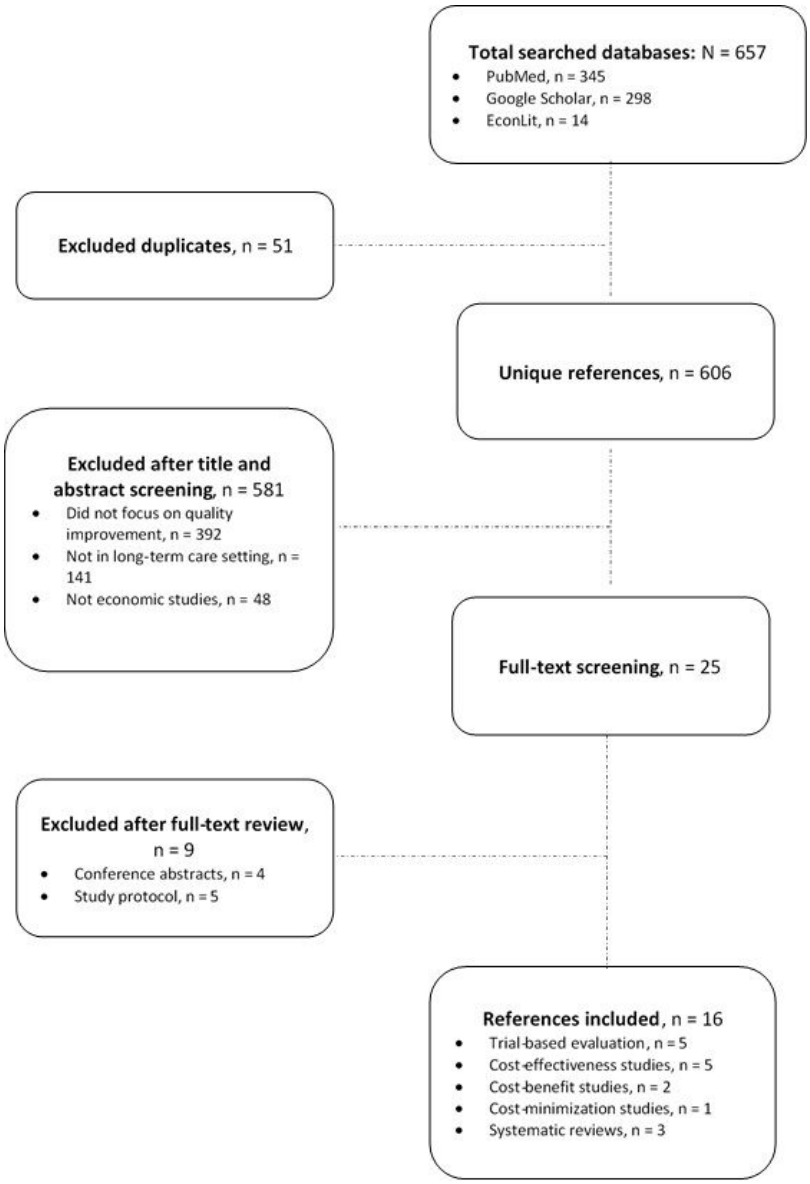


**Figure 1**

Selection of references for this review