Economic evaluation of physical activity interventions for type 2 diabetes management: a systematic review

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Background: Economic evaluation of physical activity interventions has become an important area for policymaking considering the high costs attributable to physical inactivity. However, the evidence for such interventions targeting type 2 diabetes control is scarce. Therefore, the present study aimed to synthesize economic evaluation studies of physical activity interventions for type 2 diabetes management. Methods: A systematic review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta- Analyses 2020 statement (PROSPERO reference number CRD42021231021). An electronic search was performed in PubMed, Web of Science, Cochrane Library and NHS Economic Evaluation Database. Studies were eligible if they included: adults with type 2 diabetes; any physical activity intervention in the community settings; an experimental or quasi-experimental design; and a parameter of economic evaluation [cost analysis of interventions, cost-effectiveness analysis (including cost-utility analysis) and cost-benefit analysis] as an outcome. Results: Ten studies were included in this review: seven were randomized controlled trials and three were quasi-experimental studies. All studies included direct costs, and four also included indirect costs. Four studies demonstrated that physical activity interventions were cost-saving, six studies showed cost-effectiveness, and two studies reported cost-utility. The estimates varied considerably across the studies with different analytical and methodological approaches. Conclusion: Overall, this systematic review found that physical activity interventions are a worth investment for type 2 diabetes management. However, comparability across interventions was limited due to heterogeneity in interventions type, design and delivery, which may explain the differences in the economic measures.

Introduction

Diabetes is a major public health challenge of the century. In the last two decades, the prevalence of diabetes has increased alarmingly worldwide. In 2021, it was estimated that 537 million adults aged 20–79 years were diagnosed with diabetes. Obesity and physical inactivity have been associated with the increase in the prevalence of type 2 diabetes (T2D)—which accounts for around 90% of all diabetes cases worldwide.

Physical activity is critical to the prevention and management of T2D. Studies have shown that physical activity decreases glycated hemoglobin, insulin resistance, fasting blood glucose, body mass index, body fat, blood lipids and blood pressure. Unfortunately, most people living with T2D remain physically inactive, and are, therefore, missing the opportunities to capitalize on the benefits, such as the reduced risk of cardiovascular events and overall mortality, and lower healthcare costs. Recent studies showed that physical inactivity is costly and associated with a considerable disease burden. In 2013, physical inactivity was estimated to cost the healthcare system $53.8 billion globally, and, T2D to cost $37.6 billion to the healthcare system. Physical inactivity-related deaths also contributed to at least $13.7 billion in productivity losses and were responsible for 13.4 million disability-adjusted life-years worldwide.

The economic evaluation of physical activity interventions plays an important role in informing policymaking and resource allocation, considering the constrained resources and competing priorities. In recent years, the economic evaluation of physical activity interventions has become an increasingly common practice. Evidence shows that some physical activity interventions are very cost-effective, such as various school-based interventions among children and adolescents, interventions using pedometers among adults, fall prevention programs among older people, and mass media campaigns and environmental approaches for the general population.

Among people living with T2D, studies have found a varying degree of cost-effectiveness. Examples of interventions include intensive blood pressure control in individuals with T2D (e.g., angiotensin-converting enzyme inhibitor therapy for intensive blood pressure control compared with standard blood pressure control); the use of pioglitazone plus metformin, a reportedly cost-saving therapy when compared with rosiglitazone plus metformin; comprehensive foot care to prevent ulcers compared with the usual care; counseling and treatment for smoking cessation compared with no counseling and treatment; intensive glycemic control in persons with newly diagnosed T2D compared with conventional glycemic control. However, evidence regarding the economic evaluation of physical activity interventions for T2D management remains scarce.

Therefore, we aim to systematically review economic evaluation studies of physical activity interventions for T2D management. Specifically, we aimed to summarize cost analysis of interventions (CAI), cost-effectiveness analysis (CEA) (including cost-utility analyses [CUA]), and cost-benefit analysis (CBA) of physical activity interventions in T2D.
By synthesizing and critically appraising existing economic evaluation studies of physical activity interventions in T2D, this study intends to assist decision makers with resource allocation and intervention selection.16

Methods
This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement17 (Supplementary file S1). The protocol of this systematic review was registered in PROSPERO—reference number CRD42021231021.

Eligibility criteria
Studies were eligible if participants were adults diagnosed with T2D; included any physical activity intervention in the community settings; included experimental and quasi-experimental studies; outcome measures included a parameter of economic evaluation—CAI, CEA (including CUA) or CBA.
We excluded studies with multicomponent interventions (e.g. combined physical activity and diet), and studies with multimorbidity including T2D but without separate data for T2D.

Information sources
Electronic searches were conducted in PubMed, Web of Science, Cochrane Library and NHS Economic Evaluation Database.

Search strategy
For database search, we used the following keywords: (‘physical activity’ OR exercise OR ‘active transport’ OR ‘active mobility’ OR ‘active commuting’ OR ‘active travel’ OR walking OR cycling OR running OR training OR sport*) AND (diabet* OR ‘glycemic control’ OR ‘glycaemic control’ OR ‘glucose control’) AND (cost* OR cost-effectiveness OR cost-utility OR cost-benefit OR ‘economic evaluation’ OR ‘economic analysis’ OR ‘economic assessment’ OR ‘economic impact’). We did not apply language and date limits to the searches.
Detailed search strategy is available in Supplementary file S2.

Selection process
Two authors (A.B. and R.M.) independently reviewed the search results and screened records retrieved from databases according to predefined steps. First, records were screened based on the information from the title and abstract. Second, potentially relevant articles were retrieved for full-text reading and to determine their eligibility. In case of disagreement, the consensus was reached through discussion.

Data collection process
Two authors (A.B. and R.M.) independently extracted data from eligible studies. Then, retrieved data were compared and discussed if discrepancies existed. A third author (S.W.) reviewed entered data for accuracy. In case of unclear information, the original studies’ authors were contacted to provide additional clarification.

Data items
We considered studies eligible if they presented at least one of the following economic evaluation outcomes:

- Cost analysis of interventions (CAI): estimation of the costs of an intervention’s implementation. It can include direct costs (costs of resources used to design and implement an intervention, such as personnel time, facility rent, supplies, and medications), productivity losses (impacts of patient participation in an intervention, such as work time lost or leisure-time lost due to participation in the intervention) and intangible costs (non-financial costs, such as pain and suffering, which impose a major burden on individuals).18
- Cost-effectiveness analysis (CEA): comparison between the costs and the effectiveness of two or more interventions with effectiveness measured in the same units. The incremental cost-effectiveness ratio (ICER) is used to compare interventions—the difference in costs divided by the difference in health effects. Health effects are frequently measured through quality-adjusted life-years (QALYs) gained, disability-adjusted life-years (DALYs) averted, reduction of glycated hemoglobin, increase in daily steps, reduction in body fat, etc.19 Generally, when the effectiveness is measured through QALYs, the term cost-utility analysis (CUA) can be used.15
- Cost-benefit analysis (CBA): comparison of the costs (including those of implementing an intervention) and benefits (including those resulting from an intervention, such as medical costs averted, productivity gains and the monetized value of health improvements) of an intervention. The unity of analysis is monetary.18

For each study, we summarized the following characteristics: first author, year of publication, country, design, intervention and comparison groups (type, duration, measurement, mode of delivery), study length, setting, condition (e.g. T2D vs multimorbidity of T2D), sample size (including sample size for each group, if available), and participants’ age and sex. In addition, we extracted the following methodological information from the studies: the perspective of the analysis, type of economic evaluation, cost analysis, and health outcomes. Finally, we extracted the key findings and the authors’ interpretation of the economic evaluation.

Study quality assessment
The assessment of the reporting quality of economic evaluation studies was performed by two independent authors (A.B. and R.M.), using the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) statement.20 This statement consists of a 24-item checklist subdivided into six main categories: (i) title and abstract; (ii) introduction; (iii) methods; (iv) results; (v) discussion; and (vi) other.

Effect measures
CAI usually considers the total cost of the interventions’ implementation. For CBA, the expected monetary benefits of the intervention are subtracted from the total cost of the interventions’ implementation. For CEA (including CUA), interventions can be classified as cost-saving (an intervention that generates a similar health outcome with fewer costs than the comparison intervention) or cost-effective, according to the interpretation of the intervention impact in the variable that is used to measure the effectiveness (e.g. reduction in glycated hemoglobin, increase in daily steps, reduction in body fat, reduction in medications prescription). ICER—the difference in costs divided by the difference in health effects—is commonly used to measure cost-effectiveness and cost-utility, and it can be compared with thresholds based on per capita national incomes, benchmark interventions, or league tables.19

Synthesis methods
We conducted a narrative synthesis of included studies.
For the comparison of national estimates from different years and in different currencies, we converted all to purchasing power parity (PPP) international dollars using conversion factors provided by the World Bank,21 and considering the cost estimate year that studies provided. If a study did not mention the year used in cost analysis, we assumed the cost was the year of publication.
We did not perform meta-analysis to synthesize the results since we found many sources of heterogeneity across the studies.22
Results

**Study selection**

A total of 5323 references were identified in the initial search in electronic databases. After the duplicated studies \((n = 1514)\) were removed, 3809 studies remained. After screening for the title and abstract, 3508 papers were excluded, and 301 studies were eligible for full-text reading, from which 291 were removed. Thus, the selection process resulted in the inclusion of 10 studies in the qualitative synthesis (figure 1).

**Study characteristics**

The study characteristics included in this review are shown in table 1. All studies were published in English, between 1988 and 2021. Half of the studies were conducted in the USA\(^{23–25}\) and Canada.\(^{26,27}\) Seven studies were randomized controlled trials (RCT)\(^{23,24,26,28–31}\) and three were quasi-experimental studies.\(^{25,27,32}\) All studies included interventions conducted in the community settings, although one study also included a hospital setting.\(^{30}\) The length for included studies varied from 14 weeks to 24 months.

All studies included participants with T2D. Eight studies included only patients with T2D,\(^{23,24,26–30,32}\) and two studies had individuals with other chronic conditions but provided data for T2D.\(^{29,31}\) The participants’ age ranged from 18 to 91, and most participants were middle-aged.

Regarding interventions, three were walking programs,\(^{27,29,30}\) and eight were multicomponent exercise programs (e.g. aerobic, resistance, combined aerobic and resistance exercise programs, etc.).\(^{23–26,28–32}\) Two interventions additionally included phone calls for monitoring weekly minutes of physical activity and counseling.\(^{29,32}\) Two interventions included pedometers\(^{27,31}\) and one intervention included a heart rate monitor\(^{29}\) for physical activity self-monitoring.

Most of the comparator groups included participants who followed usual care,\(^{24,26–28,30,31}\) one study had education,\(^{23}\) one included a walking program only\(^{29}\) and one received a pedometer only.\(^{27}\)

**Study quality assessment in studies**

The assessment of methodological quality for each study is presented in Supplementary file S3.

Most of the studies adhered to the CHEERS checklist in the categories of title and abstract, introduction, discussion and other. All the studies did not comply with methods and results’ items, especially the choice of model, assumptions and uncertainty characterization.

**Results of individual studies and synthesis**

Results of individual studies are presented in table 2. Four studies took the sole perspective of healthcare,\(^{23,25,28,29}\) four studies combined healthcare and societal perspectives\(^{24,26,31,32}\) and two studies the payer perspective.\(^{27,30}\)

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### Table 1: Study Characteristics

| Characteristics | Details |
|-----------------|---------|
| Language        | English |
| Countries       | USA, Canada |
| Study Type      | RCT, quasi-experimental |
| Setting         | Community, Hospital |
| Participants    | T2D, other chronic conditions |
| Age             | 18–91 years |
| Interventions   | Walking, Multicomponent exercise |
| Comparator      | Usual care, Education, Walking program, Pedometer |

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**Figure 1 PRISMA 2020 flow diagram.** PA, physical activity; T2D, type 2 diabetes
## Table 1 Characteristics of included studies

| Author, year | Country   | Study design | Intervention group | Comparison group | Length | Setting   | Condition            | Sample (n) | Age range (mean ± SD, years) | Sex          |
|--------------|-----------|--------------|--------------------|------------------|--------|-----------|----------------------|------------|------------------------------|--------------|
| Brun et al., 2008<sup>28</sup> | France    | RCT          | Exercise program (including brisk walking, jogging or gymnastics) | Usual care | 12 months | Community | T2D                  | 25 (13 IG, 12 CG) | 40–85 (59.7 ± 2)           | M + F (26.0% F) |
| Coyle et al., 2012<sup>24</sup> | Canada    | RCT          | Aerobic exercise; resistance exercise; combined exercise | Usual care | 6 months  | Community | T2D                  | 251        | 39–70 (54.2)                | M + F (34.9% F) |
| Di Loreto et al., 2005<sup>12</sup> | Italy     | Quasi-experimental | Exercise counseling + phone calls + sessions in outpatient clinic | None       | 24 months | Community | T2D                  | 179        | >40 (62 ± 1)                | M + F         |
| Johnson et al., 2015<sup>23</sup> | Canada    | Quasi-experimental | Pedometer-based walking program | Usual care with a pedometer but without instructions | 6 months  | Primary Health Care | T2D                  | 186 (94 IG, 92 CG) | ^18 (59.3 ± 8.3)     | M + F (50.0% F) |
| Kaplan 1988<sup>23</sup> | USA       | RCT          | Exercise; diet; diet + exercise | Education     | 18 months | Community | T2D                  | 76         | 53.8 ± 8.0 exercise; 54.9 ± 12.3 diet; 56.9 ± 8.9 diet + exercise; 54.5 ± 8.8 CG | M + F (57.9% F) |
| Kuo et al., 2021<sup>24</sup> | USA       | RCT          | Exercise program (EXER); CBT; combined exercise program (EXER) + CBT | Usual care | 15 months | Community | T2D with major depressive disorder | 140 (EXER 34, CBT 36, EXER + CBT 34, CG 36) | 56.0 ± 10.7 | M + F (76.0% F) |
| Marios et al., 2012<sup>25</sup> | Australia | RCT          | Walking exercise program monitored by heart rate monitors + phone calls | Walking program | 6 months  | Community | T2D                  | 26 (15 IG, 11 CG) | 18–80 (60.3 ± 9.4 IG; 65.1 ± 7.9 CG) | M + F (33.0% F in IG; 64.0% F in CG) |
| Pepin et al., 2020<sup>26</sup> | USA       | Quasi-experimental | Aerobic + resistance + balance exercise program | None       | 12 months | Community | Multimorbidity        | 453        | 31–91 (67 ± 10)            | M + F (6.0% F) |
| Sultana et al., 2018<sup>27</sup> | Malaysia  | RCT          | Aerobic exercise; combined (aerobic + resistance/strengthening) exercise program | Usual care | 14 weeks  | Community; hospital | T2D                  | 75 (25 aerobic training, 25 combined, 25 CG) | 40–60 | M + F                      |
| Taylor et al., 2020<sup>21</sup> | UK        | RCT          | Exercise referral schemes + e-coachER (a pedometer + fridge magnet with PA recording sheets, and a user guide to access the web-based support in the form of seven ‘steps to health’) | Exercise referral schemes alone | 12 months | Community | Multimorbidity        | 450 (224 IG, 226 CG) | 50 ± 13 IG, 51 ± 14 CG  | M + F (64.0% F) |

CBT, cognitive behavioral therapy; CG, control group; F, female; IG, intervention group; M, male; RCT, randomized controlled trial; SD, standard deviation; T2D, type 2 diabetes.
### Table 2 Results of individual studies

| Study                  | Perspective | Economic evaluation | Cost analysis                                                                 | Health outcomes                                                                 | Findings                                                                 | Authors’ interpretation of the economic evaluation |
|------------------------|-------------|---------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------|---------------------------------------------------|
| Brun et al., 2008      | Healthcare  | CEA                 | Costs: • Direct costs: number and duration of hospitalizations, number of outpatient consultations with the family physician or specialists, drugs prescribed and analyses performed. • Indirect costs: periods of not working, job loss and unemployment. | Body composition, fitness, metabolic balance, diabetes treatment.             | There was no significant change in body composition, blood pressure, lipid profile and glycated hemoglobin in IG, compared with CG; there was a significant reduction (26%) in insulin resistance from 3.39 ± 0.76 to 2.58 ± 0.47 ($P < 0.05$), in the IG, while tended (non-significantly) to increase in the CG (from 2.75 ± 0.59 to 4.34 ± 1.22). Regarding fitness, the intervention prevented loss of maximum aerobic capacity (decreased in the CG, $P = 0.014$), and resulted in a higher maximum power output ($P = 0.041$) and 6-min walking distance ($P = 0.020$). Indirect costs: none. Direct costs: IG required no hospitalizations, the CG spent 1.27 days in hospital ($P = 0.047$) (range: 0–5 days, corresponding to a mean total cost of $1250.25). The total cost of healthcare dropped by 50% in the IG ($1.87 ± 1 per day vs. $3.40 ± 1.67 per day, $P = 0.018$). The difference in disease-related costs after versus before the study was -0.26 per day in the CG versus $0.009 per day in the IG ($P = 0.002$). There was a significant reduction in sulfonyl urea treatments (~13.7 ± 6%, $P < 0.05$) in IG, compared with CG. The IG also reduced metformin, acarbose and insulin treatments. | Intervention is cost-saving. |
| Coyle et al., 2012     | Healthcare; societal CAI CEA assessed by ICER (the additional costs per QALYs) | CEA assessed by ICER                                                      | Costs: • Intervention costs: lifetime membership to a health club and exercise specialist. • Direct costs: costs of managing T2D with or without complications. | Life expectancy and quality-adjusted life expectancy.                      | The combined exercise was the most expensive ($32445.18), followed by the aerobic exercise ($31797.08), the resistance exercise ($31027.47) and no exercise program ($25174.38). Both life expectancy and quality-adjusted life expectancy were highest for the combined exercise (life-years = 11.79, QALYs = 8.94) compared with aerobic exercise (life-years = 11.57, QALYs = 8.77), resistance exercise (life-years = 11.51, QALYs = 8.73), and no exercise program (life-years = 11.48, QALYs = 8.70). The ICER was $167682.01 per QALYs, $94615.96 per QALYs, and $30680.74 per QALYs for the resistance, aerobic and combined exercise programs, respectively, compared with no exercise program. The ICER for the combined program was $3882.08 per QALYs compared with aerobic exercise, and $6942.70 per QALYs compared with the resistance exercise. The combined exercise resulted in the greatest increase in life expectancy and quality-adjusted life expectancy. At a maximum value of $61.72 per QALYs, the combined exercise remained cost-effective compared with the three alternatives. | The combined exercise program is more cost-effective than aerobic, resistance or no exercise program in the improvement of T2D control |

(continued)
### Table 2 Continued

| Study                                      | Perspective | Economic evaluation | Cost analysis                                                                 | Health outcomes                                                                 | Findings                                                                                       | Authors’ interpretation of the economic evaluation |
|--------------------------------------------|-------------|---------------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Di Loreto et al., 2005                      | Healthcare; societal | CEA                 | Costs • Direct costs: expenses for medications and other costs usually paid by the National Health Service (e.g. counseling intervention, laboratory testing, hospitalization and outpatient care). • Direct social costs include the value of participants’ time spent in practicing exercise, cost of related items (shoes, fitness equipment, etc.), transportation to exercise places and admission to health clubs. • Indirect social costs: include the time that participants reported as lost from work or usual activities as a result of counseling visits, illness or injury; each day lost to morbidity was valued at $100 | Improvement in the 10-year coronary heart disease risk, glycemic control and cardiovascular risk factors, reduction in medical and social costs. | There were significant ($P < 0.0001$) reductions in body weight, body mass index, waist circumference, fasting plasma glucose, glycated hemoglobin, systolic and diastolic blood pressure, heart rate, total and LDL cholesterol, and triglycerides; and 3% reduction in 10-year coronary heart disease risk; there was a significant ($P < 0.0001$) increase in HDL cholesterol. Improvements in glycemic control and cardiovascular risk factors were associated with significant ($P < 0.0001$) reductions in medical and social costs, for a total saving of $855 per capita per year. METs per hour per week were inversely related with medical prescription costs ($r = 0.51$, $18$), other medical costs ($r = 0.33$, $23$), indirect social costs ($r = 0.40$, $36$) and total costs ($r = 0.60$, $66$), and positively related with direct social costs ($r = 0.44$, $13$), $P < 0.0001$. A 3-mile daily walk was estimated to reduce medication costs by $550$, other medical costs by $700$, indirect social costs by $1100$ and total costs by $2000$, and to increase direct social costs by $400$. After 24-month, the number of subjects on insulin therapy fell by 25% (before 59/179, after 44/179, $P = 0.0003$). There was a significant ($P < 0.0001$) inverse correlation between METs per hour per week and daily units of insulin ($r = 0.38$, 0.35 IU/day). | Intervention is cost-saving.                                                                 |                                                                                                                                                      |
| Johnson et al., 2015                        | Payer       | CEA assessed by ICER  | Costs • Intervention costs: included activity time and training of the exercise specialists, administrative support personnel, recreation facilities, supplies, equipment and primary care networks’ overhead. • Healthcare costs (direct costs): physician services, hospital outpatient visits and hospital inpatient admissions. | Change in daily steps. | The total costs of the intervention were $274.21$ per participant. IG incurred less cost in all categories (physician, out- and inpatient costs) than the CG during the follow-up period. The difference in total costs between-groups was $82.26$ per participant. Daily steps increased for the IG compared with CG at 3 months (1292 vs. 418) and 6 months (1481 vs. 336), $P = 0.002$. IG had an incremental rate of 919 steps, compared with an unadjusted increment of 393 steps in CG, $P < 0.001$. The ICER was $89.52$ per 1000 daily steps. | The total costs of the program were approximately $1000$ per participant. | The diet costs $10 870$ per well-year. The diet and exercise groups have cost-utility, compared with other behavioral programs. |
| Kaplan, 1988                                 | Healthcare | CUA measured as the additional cost per well-year. | Costs • Direct costs: history and physical examination, laboratory charges, ECG evaluations, charges for behavior modification sessions, and charges for medical consultation. | Quality of well-being. | The diet -- exercise group showed improvement in quality of well-being throughout the study, with a decrease at 12 months. The diet and exercise groups had experienced 0.06 units of improvement on the quality of well-being at 18 months, compared with $−0.04$ for the CG (difference equal to 0.092 quality of well-being units, $P < 0.01$). The cost-utility ratio was $10 870$ per well-year. | (continued)                                                                 |
| Study | Perspective | Economic evaluation | Cost analysis | Health outcomes | Findings | Authors’ interpretation of the economic evaluation |
|-------|-------------|---------------------|---------------|-----------------|----------|--------------------------------------------------|
| Kuo et al., 2021<sup>24</sup> | Healthcare; societal | CEA | Costs | Incidence of clinical outcomes (e.g. stroke, cardiovascular death, myocardial infarction), life expectancy and quality-adjusted life expectancy. | Per participant, intervention-related costs over 15 months were $1615, $1532, $1983 and $2138 for the CG, exercise program, CBT and exercise program + CBT groups, respectively. Over a 10-year period, the exercise program + CBT was associated with the longest quality-adjusted life expectancy (5.355 QALYs), followed by exercise program (5.047), CBT (4.955) and CG (4.665). The exercise program resulted in the lowest total costs over 10 years ($75714). Healthcare perspective: compared with CG, the exercise program strategy saved $313 per patient and produced 0.382 more QALYs and gained 0.690 more QALY (ICER of $600 per QALY). Compared with exercise program, exercise program + CBT cost $716 more and gained 0.308 more QALY, (ICER of around $2300 per QALY gained). Societal perspective: the exercise program strategy saved $126. Compared with CG, the ICER of exercise program and exercise program + CBT was around $800 and $2000 per QALY gained. Compared with exercise program, the ICER for exercise program + CBT was around $3500 per QALY. Exercise program and exercise program + CBT interventions are cost-saving; exercise program + CBT is more cost-effective than exercise program or CBT alone. |
| Marios et al., 2012<sup>29</sup> | Healthcare | CAI | Costs | Exercise adherence (number of hours of exercise completed), improvements in peak maximal oxygen uptake, glycated hemoglobin and quality of life; cost-effectiveness of exercise training compared with pharmacological therapy. | The total cost of administering the telemonitored exercise program was $27 300, or $1050 per patient. Costs per patient are similar to the costs that would be borne by the patient for using low dose insulin ($800) and a blood pressure agent ($130) for 6 months. IG completed a mean weekly volume of 138 min, moderate intensity exercise, while CG patients completed 58 minutes weekly (P < 0.02). In the IG, peak of maximal oxygen uptake increased (5.5%), and treadmill time (18%) and maximum heart rate (3%) were significantly greater at 6 months, compared with CG (P = 0.04). Glycated hemoglobin did not change significantly after 6 months (P = 0.46). No significant between-group changes were seen for quality of life. The amount invested in intervention is comparable with other health interventions and it improved some health outcomes. |
| Pepin et al., 2020<sup>25</sup> | Healthcare | CEA | Costs | Changes in medication use and cost of medication classes commonly prescribed in the management of chronic conditions. | After 12 months, participants reduced the number of active prescriptions by 25%, 65% had no change and 10% increased diabetes medication, a net change of 14% decrease in diabetes medications. Fifty-five percent of patients had a decrease in their overall number of fills, with an average associated cost decrease of $473 per fill, or $117254 overall. A net reduction was found in diabetes medications ($2.212). Intervention is cost-saving. |

(continued)
| Study                        | Perspective          | Economic evaluation | Cost analysis                                                                 | Health outcomes                                      | Findings                                                                                                                                     | Authors’ interpretation of the economic evaluation |
|------------------------------|----------------------|---------------------|-------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Sultana et al., 2018<sup>60</sup> | Payer                | CAI                 | CEA assessed by ICER (the additional cost per health status)                  | Glycated hemoglobin and health status.               | Direct costs: $2193.71 and $2147.60 for combined and aerobic exercise interventions, respectively. There were significant improvements in glycated hemoglobin between aerobic exercise versus CG, and combined exercise versus CG, \( P < 0.001 \). There were significant improvements in health status between aerobic exercise versus combined exercise (\( P = 0.003 \)), and combined exercise versus CG (\( P < 0.001 \)). The ICER of combined exercise was $5.56 per health status; ICER of aerobic exercise intervention was $827.03 per health status. | Combined exercise program is more cost-effective than aerobic exercise or CG. |
| Taylor et al., 2020<sup>31</sup> | Healthcare; societal | CAI                 | CUA measured as the additional cost per QALYs                               | Quality of life, and minutes of moderate and vigorous PA in ≥10-min bouts. | The average cost per participant was $1970.30 and $2607.19 in the CG and IG, respectively, not statistically significant. The IG (mean 0.662, 95% CI 0.625–0.701) had more QALYs than the CG (mean 0.637, 95% CI 0.585–0.688). The difference in QALYs (0.026, 95% CI 0.013–0.040) between groups was statistically significant. Compared with the CG, the IG cost an additional $24552.36 per QALYs. IG had a weak indicative effect on total weekly minutes of moderate and vigorous PA in bouts of ≥10 min (mean difference 11.8 min, 95% CI –2.1 to 26.0 min), compared with CG. Compared with the CG, the IG cost $25.58 per additional minute of moderate and vigorous PA in a bout of ≥10 min. Compared with the base-case findings, subgroup analysis showed the intervention to be more cost-effective in groups that reported that T2D was the primary reason for referral (ICER $21645.62 per QALYs). | Cost-utility of IG compared with CG in increasing the quality of life. Cost-effectiveness of IG compared with CG in increasing minutes of moderate and vigorous PA ≥10-min bouts. |

CAI, cost analysis of interventions; CBT, cognitive behavioral therapy; CEA, cost-effectiveness analysis; CG, comparator group; CUA, cost-utility analysis; IG, intervention group; MET, metabolic equivalent of task; PA, physical activity; QALYs, quality-adjusted life years; T2D, type 2 diabetes.
All studies included estimates of direct healthcare costs of physical activity interventions. Direct costs included medical costs (outpatient care, laboratory testing, expenses with medications, hospitalizations and emergency care). Four studies also provided indirect costs, and included periods of not working, job loss and unemployment, and participants’ time spent in physical activity sessions.

Regarding economic evaluation, nine studies included CEAs, and two studies used CUA. No CBA was identified in this review.

Physical activity interventions were reported as being cost-saving in four studies, six were considered cost-effective, and two with cost-utility (table 3). In conclusion, this systematic review found that physical activity interventions for type 2 diabetes control are a worth investment for type 2 diabetes management and its cost-effectiveness, increase the reliability of findings and, ultimately, promote their use by policymakers.

Future research should involve larger studies with robust designs to establish the effects of physical activity interventions on T2D management and its cost-effectiveness, increase the reliability of findings and, ultimately, promote their use by policymakers.

It would also be important to investigate the impact of physical activity interventions on long-term outcomes related to T2D, namely in the incidence of cardiovascular diseases, micro- and macrovascular complications, years of life lost, and mortality. Furthermore, it was possible to note that long-term follow-up studies tend to be more cost-effective given that health benefits often last beyond the study period.

Conclusion

In conclusion, this systematic review found that physical activity interventions are a worth investment for type 2 diabetes management. However, due to the studies’ heterogeneity, it is challenging to compare interventions across studies.

Studies with a societal perspective and robust analysis over wider time horizons are needed to explore the potential of physical activity interventions in the effectiveness and cost-effectiveness of T2D management over the long term. This will allow for efficient resource allocation by policymakers across the sectors involved in implementation programs.
Supplementary data

Supplementary data are available at EURPUB online.

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Disclaimer

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Data availability

The data underlying this article will be shared on reasonable request.

Key points

- Physical activity interventions are a good investment for type 2 diabetes management.
- Health benefits of physical activity interventions last beyond the intervention period.
- Future studies should include a societal perspective, robust design and accurate reporting to better inform resource allocation and decision making.

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