

Exercise as Medicine—Evidence for Prescribing Exercise for the National Health Priority Areas: An Umbrella Review

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ABSTRACT

Objective: To describe the relationship between exercise and Australia's nine national health priority areas (NHPAs), which are arthritis and musculoskeletal conditions, asthma, cancer control, cardiovascular health, dementia, diabetes mellitus, injury prevention and control, mental health conditions, and obesity.

Materials and methods: CINAHL, Cochrane Database of Systematic Reviews, PubMed, and SPORTDiscus were searched from 2007 to 2017, inclusive. Included were systematic reviews and meta-analyses reporting the effect of exercise on development, management, and treatment of Australia's NHPAs.

Results: A total of 74 studies were fulfilling the inclusion criteria. Moderate exercise effectively treats and manages symptoms of osteoarthritis. Exercise improves maximal oxygen uptake in patients with asthma, prevents breast cancer, and reduces hospital admissions for patients with heart failure. Exercise significantly reduces the risk of type II diabetes mellitus and assists weight control. Exercise reduces the risk of vascular dementia, delays cognitive decline, and is effective in falls prevention. Exercise reduces symptoms of anxiety and is an effective treatment for people with depression.

Conclusion: Exercise had a positive/beneficial effect in all nine NHPAs. However, it doesn't have universal beneficial effect for every subdisease. From a clinical perspective, prescription of exercise to assist in the management and/or prevention of all of the nine NHPAs should be encouraged.

Implications for public health: Exercise has a critical role in the national public health strategy for the prevention and treatment of diseases related to inactivity.

Keywords: Exercise, National health priority areas, Physical activity, Review.

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INTRODUCTION

Australia's Commonwealth, state, and territory governments established the National Health Priority Areas (NHPAs) initiative in 1996 in response to the World Health Organization's global strategy Health for all by the year 2000. Arthritis and musculoskeletal conditions, asthma, cancer control, cardiovascular health, dementia, diabetes mellitus, injury prevention and control, mental health, and obesity are the nine NHPAs and were chosen due to their significant contributions to the burden of disease in Australia.¹ These health priority areas are similar to those in many other Western countries and represent both the major causes of death and chronic morbidity in many nations.

It is widely recognized that regular physical activity can prolong life, reduce the risk of cardiovascular disease, stroke, diabetes, cancer, osteoporosis, and improve mental health.² There is strong evidence that a higher risk of mortality is associated with physical inactivity and sedentary behavior.^{3,4} For example, inactivity is attributable to 6% of coronary heart disease (CHD), 7% of type II diabetes mellitus (T2DM), 10% of breast cancer, and 10% of colon cancer globally.² Accordingly, the Australian government has recognized that exercise has a critical role to play in Australia's national public health strategy for prevention of diseases related to inactivity.^{3,4}

However, activity levels among the Australian population remain low and according to the 2014–15 national health survey (NHS), only 55% of adults meet the recommended physical activity guidelines.⁴ The lack of sufficient physical activity in Australia is again echoed by a similar problem being noted in the majority of Western nations.

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Currently, no reviews are available to explore the effect of exercise on Australia's nine NHPAs. The aim of this umbrella review is to examine the empirically published literature and describe the relationship between exercise and Australia's nine NHPAs.

MATERIALS AND METHODS

An *a priori* study protocol was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines^{5,6} and the Joanna Briggs Institute (JBI) reviewers manual—methodology for JBI umbrella

reviews.⁶ The study protocol was registered on the PROSPERO International prospective register for systematic reviews (<http://www.crd.york.ac.uk/PROSPERO/>; registration number 42017073364).

Inclusion/exclusion criteria were developed⁷ (Appendix A) and four databases (CINAHL, Cochrane Database of Systematic Reviews, PubMed, and SPORTDiscus) were systematically searched from January 2007 to July 2017 inclusive, using criteria illustrated in Appendix B. Systematic reviews and meta-analyses published in a peer-reviewed journal reporting exercise and one or more of the nine NHPAs were included and the titles and abstracts were independently screened by the lead author against the criteria (Appendix A) and checked by a second author (NKPP). Relevant full-text articles were then screened by the lead author. A publication was excluded from the review if it failed a single criterion and the first “no” response to any item on Appendix A was the primary reason for exclusion. When there were two or more studies available for the same topic including a Cochrane review, then the Cochrane review was selected to include in the analysis. This was because Cochrane reviews are internationally recognized as the highest standard in evidence-based health care resources. If multiple reviews were available for the same topic and there was absence of a Cochrane review, then the review with the highest AMSTAR rating was selected.

Methodological quality of the included papers was assessed independently using the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) tool⁸ by two reviewers (PI, NKPP). When there was a lack of consensus, the consensus was reached via discussion. Agreement between reviewers was determined by Kappa statistic. The lead author extracted the following key variables from the reviews: authors, year of publication, review summary, findings related to the effect of exercise on disease development, treatment, mortality, and secondary clinical outcomes such as quality of life (QOL).

RESULTS

Of the 3,205 records identified in the initial keyword search, 74 reviews fulfilled the inclusion criteria and were included in the synthesis (Fig. 1).

A comprehensive collation of the 74 reviews including significant findings related to the effect of exercise on disease development, treatment, mortality, and secondary clinical outcomes such as QOL for each of the nine NHPAs is summarized Table 1 and elaborated in Appendix C. There were 11 reviews on arthritis and other musculoskeletal conditions,^{9–19} 6 reviews on asthma,^{20–25} 13 reviews on cancer,^{26–38} 7 reviews on cardiovascular disease,^{39–45} 10 reviews on dementia,^{46–55} 5 reviews on diabetes,^{56–60} 6 reviews on injury prevention and control,^{61–66} 11 reviews on mental health,^{67–77} and 5 reviews in obesity.^{78–82}

Arthritis and Other Musculoskeletal Conditions

Of the 11 reviews examining effects of exercise on arthritis and other musculoskeletal conditions,^{9–19} 4 were on osteoarthritis (OA),^{10,13,14,19} 3 on rheumatoid arthritis,^{9,11,16} 3 on lower back pain,^{12,18} and 2 on osteoporosis.^{15,17} There were six Cochrane reviews.^{10,12–16} There is high-quality evidence confirming that moderate exercise can be effectively used to treat and manage symptoms of OA such as pain and functioning with moderate improvements in disability and QOL.^{10,13,14,19} A 2015 Cochrane review demonstrated compatible effects of exercise to nonsteroidal anti-inflammatory

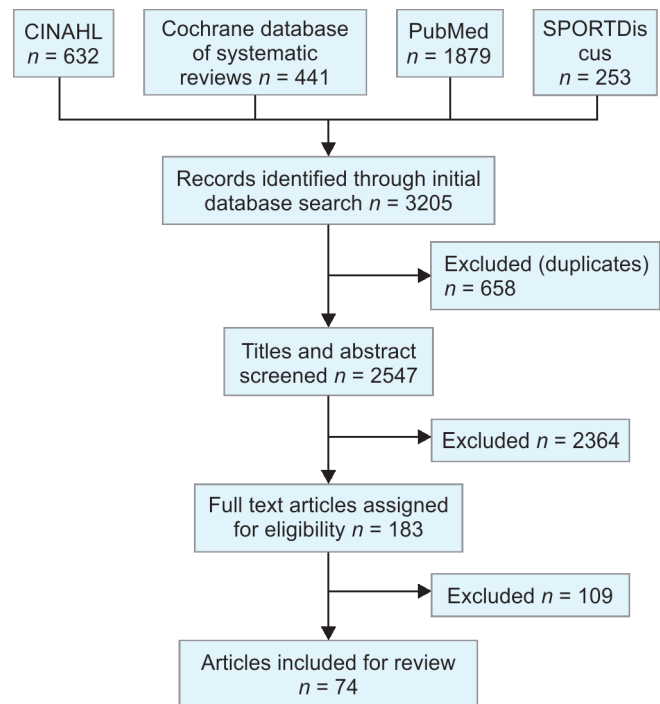


Fig. 1: PRISMA flowchart showing methodology for study inclusion

medications in the management of pain in knee OA.¹³ In relation to rheumatoid arthritis, moderate-quality evidence supports exercise in improving aerobic capacity, muscle strength, and self-reported functional ability.^{11,16}

Weight-bearing-based physical activity increases bone strength in children; however, there is insufficient evidence to support this in men and premenopausal women.¹⁷ In postmenopausal women, the most effective type of exercise on bone strength appears to be non-weight-bearing resistance activity with a relatively small but statistically significant effect when compared with control groups¹⁵ (Tables 1, 2 and Appendix C).

Asthma

Of the six reviews examining the effects of exercise on asthma,^{20–25} three focused on children.^{20,22,25} Three were Cochrane reviews.^{20,21,24} High-quality evidence demonstrated marked improvement in maximal oxygen uptake and QOL in children and adults with asthma but does not appear to improve pulmonary function.^{21,23,25} The type of exercise was not specifically determined; however, all studies focused on aerobic-based activity. Swimming is particularly beneficial for children and adolescents with asthma²⁰; however, no difference was found between water- and land-based training in adults (Tables 1, 2 and Appendix C).

Cancer Control

There were 13 reviews examining the effects of exercise on various forms of cancer.^{26–38} All forms of cancer were included in five studies^{29,31,33,36,38} and the remaining focused on breast,^{27,32,37} colorectal,³⁰ lung,³⁴ and prostate^{26,28,35} cancer. There were three Cochrane reviews.^{31,32,36} Evidence demonstrates an inverse relationship between physical activity and postmenopausal breast cancer with risk reductions ranging from 20 to 80%.³⁷ Improvements in QOL, mood, fatigue, exercise capacity, and tolerance to treatment were found with all forms of cancer^{26–29,33–36} (Tables 1, 2 and Appendix C).

Table 1: Systematic review summary of the effect of exercise on preventing and treating the nine priorities areas

<i>National health priority area</i>	<i>Effect of exercise on disease development</i>	<i>Effect of exercise on treatment</i>	<i>Effect of exercise on secondary clinical outcomes</i>
Arthritis and musculoskeletal conditions	—	Moderate exercise can be used to treat and manage OA symptoms. ^{10,13,14,19} Prevents recurrences of lower back pain. ¹² Improves bone mineral density for people with post-menopausal osteoporosis. ^{15,17}	Improves pain, functional ability, and QOL in patients with OA. ^{10,13,14,19} Aerobic and resistance training programs consistently improve aerobic capacity, muscle strength, and QOL in patients with rheumatoid arthritis. ^{9,11} Exercise needs to be tailored to individual needs. ¹¹
Asthma	—	Improves maximal oxygen uptake in children and adults but does not have any effect on pulmonary function. ^{21,22,25} Swimming is particularly beneficial for children and adolescents with asthma. ²⁰	Positive effect on cardiorespiratory fitness and improves QOL for adults and children with asthma. ^{21,22,25} Improves exercise-induced bronchoconstriction in children. ^{21,22,25}
Cancer	Prevention of breast cancer with a risk reduction of 20–80%. ³⁷ Lack of evidence to support exercise in the management of colorectal cancer. ³⁰	—	All studies except one ³² reported improved QOL. Improved symptoms including fatigue, exercise capacity, and physical functioning. ^{29–31,33,36}
Cardiovascular health	—	Reduces risk of hospital admissions in CHD ⁴⁰ and heart failure. ^{41,42,45} Cardiorespiratory training reduces disability during or after usual stroke care. ⁴⁴	Improves quality of life (QOL) in heart failure. ^{39,41,42,45} No evidence to suggest exercise rehabilitation causes harm. ^{41,42,45} No effect on cause mortality in patients with heart failure. ^{41,42,45}
Dementia	Reduces the risk of vascular dementia. ⁴⁶	Conflicting evidence as to whether exercise positively influences cognitive function in those with all types of dementia. ^{49,52}	Evidence supporting exercise to improve the performance of ADLs. ^{48,52} Improves physical functioning. ^{50,52}
Diabetes mellitus	Prevents development of T2DM. ⁵⁷ Increased risk reduction when combined with dietary interventions. ⁶⁰ Insufficient evidence to suggest exercise reduces the risk of gestational diabetes. ^{58,59}	Reduces the incidence of disease progression from pre-diabetes to T2DM. ⁶⁰	When combined with dietary modifications, exercise has favorable effects on BMI control. ⁶⁰
Injury prevention	Reduces the falls risk and has a significant role in falls prevention and reducing the number of injuries caused by falls ^{61,62,66} and reduces the fear of falling. ⁶³ Exercise-based injury prevention programs reduce the risk of acute and overuse injuries. ^{64,65}	Greatest improvement in falls prevention is interventions that include exercises that challenge balance. ⁶⁶	—
Mental health	—	Effective treatment for anxiety ^{69,72,73,76,77} and depression. ^{67,74} Better results when individually tailored. ⁷³	Improves physical health, working memory, attention, and social cognition of those with schizophrenia. ⁷¹
Obesity	—	Exercise combined with diet and behavior therapy is an effective weight loss strategy in adults who are overweight or obese. ⁸²	Improves BMI of children and adolescents who are overweight or obese. ^{78,80,81}

OA, osteoarthritis; QOL, quality of life; ADL, activities of daily living; T2DM, type II diabetes mellitus; CHD, coronary heart disease; BMI, body mass index



Table 2: Summary of positive effects of exercise in general and postulated negative effects of subtypes of exercise

<i>National health priority area</i>	<i>Positive effects of exercise (as revealed by this umbrella review)</i>	<i>Possible negative effects of any sub-form of exercise (dose or type)</i>	<i>Recommendations regarding exercise for this priority area</i>
Arthritis and musculoskeletal conditions	Moderate exercise can be used to treat and manage OA symptoms ^{10,13,14,19} and lower back pain. ¹² Weight-bearing exercise improves bone density in children and post-menopausal women. ^{17,18}	Possible “U”-shaped curve between musculoskeletal conditions and exercise intensity; for example, higher rates of OA seen in elite/extreme sports competitors. ^{83–85}	Moderate exercise can be highly recommended over sedentary behavior for generally preventing arthritis and musculoskeletal conditions. More research is needed to identify a cut-off point for type and intensity of exercise between benefit and harm.
Asthma	Improves QOL, exercise capacity, and maximal. Swimming is particularly beneficial for children and adolescents with asthma. ²⁰	Some types of exercise, particularly outdoor in cold weather, are thought to be a potential trigger of asthma attacks.	Exercise can be recommended for managing asthma, ensuring an appropriate asthma management plan is in place prior to the commencement of an exercise program
Cancer	Improves symptom control, fatigue, mood, and exercise tolerance during treatment. Prevention of some cancers, particularly breast cancer, with a risk reduction of 20–80%. ³⁷	No negative effects of exercise known.	Exercise can be highly recommended for preventing and managing some cancers such as breast.
Cardiovascular health	Exercise reduces risk of hospital admissions in CHD ⁴⁰ and heart failure. ^{41,42,45} Improves blood pressure and cholesterol control.	Theoretical reverse “J” curve with some association postulated between extreme exercise and increased risk of arrhythmias and cardiomyopathy. ⁸⁶	Exercise can be recommended for good cardiovascular health; further research is required to determine the exercise dose (if any), which becomes harmful for the heart.
Dementia	Exercise reduces the risk of vascular dementia. ⁴⁶ Improves ADL and functional performance.	Emerging evidence that recurrent concussions in collision sports (e.g., American football) may be associated with chronic traumatic encephalopathy. ⁸⁷	Exercise can be recommended for preventing dementia (perhaps with the exception of collision sports)
Diabetes mellitus	Exercise prevents the development of T2DM. ⁵⁷ Risk reduction is most effective when combined with dietary interventions. ⁶⁰	No known negative effects of exercise on T2DM.	Unequivocally, exercise can be highly recommended for prevention, management, and treatment of T2DM.
Injury prevention	Exercise incorporating balance reduces falls risk and therefore has a significant role in falls prevention and reducing the number of injuries caused by falls ^{61,62,66} and reduces the fear of falling in elderly. ⁶³ Exercise-based injury prevention programs reduce the risk of sporting injuries. ^{64,65}	Some sports, for example, those involving change of direction, are associated with injury (e.g., knee ACL tears leading to surgery ⁸⁸).	Exercise can be recommended over sedentary behavior for preventing falls. Sports (as a form of exercise) are associated with injury. Individual health benefit-risk profiles of various sports (generally health benefits vs. injury risk) need to be researched further.
Mental health	Effective treatment for anxiety ^{69,72,73,76,77} and depression. ^{67,74} Effective in reducing depressive episodes.	Anecdotal evidence (only) suggests that exercise might be psychologically addictive in some individuals.	Exercise can be recommended to maintain good mental health and psychological well-being.
Obesity	Exercise combined with diet and behavior therapy is an effective weight loss strategy in adults ⁸² and children and adolescents who are overweight or obese. ^{78,80,81}	No known negative effects of exercise on obesity.	Unequivocally, exercise can be highly recommended to prevent obesity.
Summary for all nine NHPAs	Exercise has positive health benefits in all nine NHPAs. However, the positive effects vary across NHPAs.	Highly competitive sport or extreme exercise, in particular, may have some negative effects on some NHPAs, of most concern in arthritis and musculoskeletal area.	Promotion of exercise (and exercise medicine) should be a priority for the health system. Further research needs to define dose-response cut-offs for the minority of situations where excessive exercise has some negative consequences.

OA, osteoarthritis; QOL, quality of life; ADL, activities of daily living; T2DM, type II diabetes mellitus; ACL, anterior cruciate ligament; CHD, coronary heart disease

Cardiovascular Disease

Of the seven reviews examining the effects of exercise on cardiovascular disease,^{39–45} there was one review each on atrial fibrillation,⁴³ CHD,⁴⁰ and stroke.⁴⁴ Four reviews were on heart failure.^{39,41,42,45} There were five Cochrane reviews.^{40–43,45} High-quality evidence supports exercise in the management and prevention of many precursors to cardiovascular disease including hypertension, hypercholesterolemia, and diabetes. Exercise improves QOL in patients with heart failure^{39,41,42,45} and reduces hospital admissions; however,^{41,42,45} it has no significant effect on mortality.^{41,42,45} There was no evidence to suggest that exercise rehabilitation causes harm.^{41,42,45}

Cardiorespiratory training reduces disability during or after usual stroke care through improved balance and walking tolerance. Due to a lack of studies, there is insufficient evidence to comment on the effect of exercise on mortality or cognition⁴⁴ (Tables 1, 2 and Appendix C).

Dementia

Of the 10 reviews examining the effects of exercise on dementia,^{46–55} only 1 review focused on vascular dementia.⁴⁶ There were two Cochrane reviews.^{48,55} Exercise reduces the risk of vascular dementia;⁴⁶ however, it does not reduce the risk of Alzheimer's dementia. It improves global cognition, attention, and executive function in people with mild cognitive impairment (Tables 1, 2 and Appendix C).

Diabetes

Of the five reviews examining the relationship between exercise and diabetes,^{56–60} two reviews investigated gestational diabetes.^{58,59} There were three Cochrane reviews.^{58–60} There is evidence of an inverse relationship between physical activity and the risk of developing T2DM.^{57,60} Exercise combined with diet and behavioral interventions has favorable effects on weight and body mass index (BMI) control.⁶⁰ There is no clear evidence that exercise reduces the risk of gestational diabetes⁵⁹ (Tables 1, 2 and Appendix C).

Injury Prevention and Control

Four reviews examined the role of exercise in falls prevention,^{61–63,66} and two reviews examined exercise in sports injury prevention.^{64,65} There was one Cochrane review.⁶³ Exercise reduces risk of falls, injuries caused by falls, and reduces the fear of falling.^{61,62,65} Exercise-based injury prevention programs reduce the risk of acute and overuse sporting injuries^{64,65} (Tables 1, 2 and Appendix C).

Mental Health

Of the 11 reviews examining the role of mental health,^{67–77} there were 5 reviews on anxiety,^{69,72,73,76,77} 2 on depression,^{67,74} 2 on postnatal depression,^{68,75} and 2 reviews on schizophrenia.^{70,71} There were two Cochrane reviews.^{67,71} Exercise therapy was effective in reducing symptoms of anxiety.^{69,72,73,76,77} In the treatment of depression,^{67,74} it is moderately more effective than control interventions in reducing symptoms; however, effect size was small. When compared to psychological or pharmacological interventions, exercise appears to be no more effective; however, this conclusion is based on a few small trials⁶⁷ (Tables 1, 2 and Appendix C).

Obesity

Of the five reviews examining the role of exercise in obesity,^{78–82} only one review was in adults.⁸² Exercise improves BMI of children and adolescents who are overweight or obese.^{78,80,81} Exercise

needs to be combined with diet and behavior therapy to achieve significant weight loss in adults who are overweight or obese⁸² (Tables 1, 2 and Appendix C).

METHODOLOGICAL QUALITY

The AMSTAR⁸ methodological quality assessment results and the inter-rater agreement are presented in Appendix D. The inter-rater agreement was substantial ($k = 0.872$), with raters agreeing on 770 of 814 items (94%). Consensus was reached on 50 items following discussions. A total of 14 studies^{16,20,21,24,29,31,32,36,44,48,55,58,63,67} reached maximum quality and thus have a low risk of bias. The mean score was 7.8.

DISCUSSION

Overall, exercise had a positive effect (either in prevention or treatment) in all nine NHPAs. However, it does not have a universally beneficial effect for every subdisease of the NHPAs. The strength of this umbrella review is the synthesis of the effects of exercise in such a diverse range of health conditions, with a focus on Australia's National Health Priorities. The major and obvious limitation is that when considering such a diverse range of conditions, the analysis of and scrutiny given to the systematic reviews is necessarily rudimentary. Despite this limitation, we believe that there will be little controversy regarding our conclusions, as the consistency in systematic review conclusions was very high. That is, we did not encounter many instances of contradictory high-quality recent reviews of a priority area overall. It is beyond the depth of this umbrella review, but there would be heterogeneity when analyzing the myriad subconditions in each priority area.

While our search strategy was able to identify 74 review papers showing positive associations between exercise and a disease within a NHPA, to remain unbiased, it is important to highlight potential negative effects associated with exercise, particularly in excess. The term "exercise" in isolation appears to denote (moderate) exercise, for which we have uncovered almost universally positive effects. The aim of our paper was to examine the effects of exercise (in general) as opposed to competitive, elite, or professional sport; thus, these terms were not included in our inclusion/exclusion criteria.

For arthritis and musculoskeletal conditions, injury prevention and control, and cardiovascular conditions, in particular, the effect of exercise might be a nonlinear dose-response curve with negative effects seen at high exercise doses. By contrast, moderate doses of exercise have a protective effect on both cardiovascular and musculoskeletal health. Positive effects of exercise in relation to each of the nine NHPAs found in this umbrella review and any known or postulated negative associations with exercise (either in type or excessive dose) are summarized in Table 2, to allow summary findings to be used as a quick practical guide.

According to the 2015–16 NHS, 15.3% of Australians live with arthritis⁴, and currently, there is no cure. We found that moderate exercise is effective in the treatment and management of symptoms such as pain, functioning, and QOL.^{10,13,14,19} Individually tailored exercise programs were more effective in management of OA. Overall, it is clear that moderate exercise prevents arthritis; however, prescription need to take into account possible side effects including injuries such as anterior cruciate ligament and meniscal injuries sustained by participating in some types of elite or extreme sports can lead to knee OA.^{83,84} A recent Australian study found that although a majority of sports injuries are of low severity, a significant proportion of community-level players (42%) choose to self-treat or

not to treat their injuries with many injuries relating to joints. This is concerning because poorly managed joint injuries can predispose people to the development of chronic health conditions such as OA. Primary healthcare providers have an important role in terms of education, treatment, and prevention of sports injuries.

The 2015–16 NHS reported that 11.3% of Australians have hypertension, 5.2% have heart disease, 7.1% have high cholesterol, and 5.1% have diabetes (including 4.4% with T2DM). In addition, 63.4% adults and 27.4% children are overweight or obese.⁴ Exercise improves the QOL in patients with heart failure^{39,41,42,45} and reduces hospital admissions.^{39,41,42,45} There is an inverse relationship between exercise and reducing the risk of T2DM.^{57,60} Exercise improves glucose control in those with T2DM.⁵⁶ It also induces significant weight loss in adults⁸² but need to be combined with a restrictive diet for adults who are overweight and obese with T2DM.⁵⁷ In addition, exercise improves the BMI of overweight and obese children and adolescents^{78,80,81} and reduces risk factors for cardiovascular disease. These conditions are the main component of metabolic syndrome. Given that a significant proportion of Australians are affected by metabolic syndrome, the potential burden to individuals and the government in terms of cost of health care may be onerous. Primary healthcare providers such as general practitioners require an important knowledge base in terms of exercise prescription to provide positive outcomes, both financial and educational. It may also fall to primary care services to provide appropriate resources to educate the community to facilitate effective delivery of appropriated exercise programs.

There is a small subset of cardiovascular conditions (certain hypertrophic cardiomyopathies and arrhythmias such as arrhythmogenic right ventricular cardiomyopathy (AVRC) and atrial fibrillation⁴⁰) where extreme exercise is now considered a possible risk factor for cardiovascular pathology.⁸⁹ The cut-off for cardiovascular “harm” is controversial and not well established⁸⁹ (Table 2). This should be differentiated from the paradox observed where exercising individuals overall have a much lower risk of sudden cardiac death than the general population, but if they do suffer a cardiac arrest, it is most likely to be during exercise.⁸⁶ In both the musculoskeletal and cardiovascular diseases, the negative effects of a sedentary lifestyle are almost certainly greater than the negative effects of high-intensity exercise. The concept of a “U”-shaped curve has been previously cited (both musculoskeletal⁹⁰ and cardiovascular⁹¹) to convey the concept that both inadequate and excessive exercise intensities may be harmful. The findings of our review suggest that the shape of a such graph is more likely to be an inverse “J.” The negative effect of extreme exercise loads vs moderate may exist with respect to some NHPAs but these negative effects are probably overstated.

In 2015, it was estimated that 342,800 people were living with dementia. It is Australia’s second leading cause of deaths⁹² and with the ageing population (16% of Australians over the age of 65) this is expected to grow.⁹² Physical activity prevents vascular dementia.⁴⁶ It delays cognitive decline⁵³ and improves global cognition, attention and executive function⁵⁰, and physical functioning^{50,52,54} in those with dementia. Although there was overwhelming evidence that “exercise” in general was beneficial in dementia, it is important to be aware of the concerns of the association between some high-collision sports (such as boxing and American football) and a subtype of dementia known as chronic traumatic encephalopathy (CTE).

Falls were the leading external cause of hospitalizations in older Australians with approximately 96,000 cases in 2011–12, and the rate increases with increasing age.⁹³ Exercise has a significant role in falls prevention and reduction of injury frequency.^{61,62,66} Most falls occur as a result of poor neuromuscular control, poor strength, and loss of balance. Interventions incorporating exercise that challenges balance have a great effect preventing falls.⁶⁶ This information is useful to the healthcare providers in designing and implementing exercise programs for falls prevention.

Asthma affect 10.8% Australians, with the prevalence increasing by 1% since 2007–8.⁴ Exercise improves maximal oxygen uptake and significantly improves QOL in adults with asthma²³ but does not appear to improve pulmonary function.^{21,23} There is a positive effect on cardiorespiratory fitness and exercise-induced bronchoconstriction in children²⁵ with swimming being particularly beneficial as it increases the maximal lung capacity.²⁰ With the increasing prevalence of asthma, it is important to incorporate exercise as part of the treatment regimen for improving QOL for asthma sufferers.

Anxiety affects 11.2% of Australians with 9.3% being affected by depression.⁴ Exercise was effective in reducing the symptoms of anxiety^{69,72,73,76} and treatment for people with depression.^{67,74} It should be noted that in certain instances it is as effective as psychological or pharmacological treatments.⁶⁷ Given the prevalence of mental health conditions is increasing, it is important to be aware of the role of exercise as an effective treatment.

The overall benefits of exercise clearly outweigh the associated risks with the dangers of inactivity being a risk factor for many cancers, obesity, many cardiovascular conditions, dementia, mental health conditions, T2DM, and stroke.² Inactivity is one of the major modifiable risk factors for chronic disease. However, only 55% of adults met the recommended physical activity guidelines with 30% Australians insufficiently active and 15% inactive.⁴ In the past, smoking was known as the single worst risk factor for predicting bad health at the individual level; however, in Australia, 15% of the population smoke,⁹⁴ yet, 45% of the population are insufficiently active. This increases their risk for a myriad of chronic health conditions. Exercise has well and truly become the greatest population health challenge for Australia for the twenty-first century and healthcare professionals have the responsibility to promote exercise at every opportunity so as to improve the overall health of the population.

Strengths and Limitations of this Umbrella Review

This is the first comprehensive study to collate and analyze all published systematic reviews and meta-analyses in peer-reviewed journals from January 2007 to July 2017, inclusive on the relationship of exercise on Australia’s nine NHPAs. The strength of this umbrella review is the sensitive search strategy with 3,205 articles assessed, strong methodological rigor was maintained by using an *a priori* study protocol based on the PRISMA guidelines⁵, and risk of bias assessed using the AMSTAR tool.⁸ Both highly accepted tools were used to maintain methodological rigor. Methodological quality was assessed by two independent reviewers with the substantial inter-rater agreement. Included studies were of a high methodological quality. This umbrella review, therefore, provides a reliable overview of current data pertaining to exercise and the nine NHPAs. However, the results should be interpreted with caution due to other limitations, discussed below.

The synthesis of evidence presented in this review is restricted by the reporting limitations that were presented in each included review. There was heterogeneity of findings when myriad subconditions considered for each NHPA. That is, for example, exercise is proven to be beneficial in preventing and treating individual cancers such as breast cancer,³⁷ but it has not been universally shown to be protective or able to treat all subtypes of cancer. In addition, the definition of exercise used across the studies was different; thus, this review was unable to accurately compare findings.

CONCLUSION

From a clinical perspective, prescription of exercise to assist in the management and/or prevention of all of the nine NHPAs should be encouraged. For better results and improved compliance, exercise prescription should be enjoyable, individualized, and achievable with regular follow-up and support provided. There are possible negative effects of extreme-dose or highly competitive exercise, but these are generally overstated with the effects of sedentary behavior being of far greater net harm.

PRACTICAL IMPLICATIONS FOR PUBLIC HEALTH

- Exercise has a critical role to play in Australia's national public health strategy in the prevention and treatment of disease.
- Exercise is effective to some extent in all of the nine NHPAs.
- About 45% of Australian population is insufficiently active; therefore, increased emphasis needs to be on encouraging physical activity in the general population.
- The Australian Activity Guidelines of "30 minutes of moderate-intensity activity on most, if not all days" is safe to recommend.

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Appendix A: Inclusion/exclusion criteria for “Exercise as medicine—evidence for prescribing exercise for Australia’s nine national health priority areas: an umbrella review”

	<i>Inclusion criteria</i>	<i>Exclusion criteria</i>	<i>Rationale for this criteria</i>
Publication type	Peer-reviewed systematic review and/or meta-analysis articles only.	All other publications including peer-reviewed original research papers, observational studies, non-peer-reviewed articles, newspapers, opinion pieces, editorials, commentaries and letters to the editor. Conference proceedings/abstracts. Book chapters.	Aim of the umbrella review is to synthesize the existing evidence. Where there were two or more studies available on the same topic, the AMSTAR rating was used.
Language	English language	Non-English	For reasons of practicality, it was deemed acceptable to include only studies published in English.
Publication date	2007 to 2017	Publications prior to 2007.	To ensure up to- date publications are assessed and reflect the increasing understanding within the literature and in clinical practice that exercise is medicine.
The National Health Priority Areas (NHPAs)	Arthritis and musculoskeletal conditions, asthma, dementia, diabetes mellitus, cancer control, cardiovascular health, injury prevention and control, mental health, obesity	Any other condition other than arthritis and musculoskeletal conditions, asthma, dementia, diabetes mellitus, cancer control, cardiovascular health, injury prevention and control, mental health, and obesity. For example, if the study is relating to lipid profiles, then excluded from this umbrella review as the aim of this umbrella review is to look at the NHPA/ primary problem.	The NHPAs were established in response to the World Health Organization’s global strategy Health for All by the year 2000. Arthritis and musculoskeletal conditions, asthma, cancer control, cardiovascular health, dementia, diabetes mellitus, injury prevention and control, mental health, and obesity are the nine NHPAs that contribute to the burden of disease in Australia. The aim of this umbrella review was to examine the empirically published literature to describe the relationship between exercise and the nine NHPA’s.
Outcome measures	Role of exercise in the management of the condition. Role of exercise in the treatment of the condition. Role of exercise in the QOL, well-being, and fitness levels. Role of exercise in the prevention of the condition.	Outcomes other than <ul style="list-style-type: none"> • Role of exercise in the management of the condition. • Role of exercise in the treatment of the condition. • Role of exercise in the QOL, well-being, and fitness levels., 	The primary outcomes of interest are the role of exercise in management, treatment, and prevention of the nine NHPA’s. To assist in the management and prevention of chronic disease.

Appendix B: Umbrella review search strategy

<i>Database</i>	<i>Health priority area</i>	<i>Search terms</i>	<i>Applied filters</i>	<i>Results</i>
CINAHL plus with Fill Text (EBSCOhost)	Arthritis and musculoskeletal conditions	AB ((arthritis OR musculoskeletal OR osteoporosis OR osteoarthritis OR back pain OR gout) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)	Year filter (2007–2017) Human Language filter (English)	133
	Asthma	AB ((asthma) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)	Systematic review OR meta-analysis	14
	Cancer control	AB ((cancer) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		89
	Cardiovascular health	AB ((cardio* OR cardiac* OR stroke OR thrombo*) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		134

Contd...



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Database	Health priority area	Search terms	Applied filters	Results
	Dementia	AB ((dementia) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		13
	Diabetes	AB ((diab*) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		69
	Injury prevention and control	AB ((injury prevention OR fall) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		65
	Mental health	AB ((mental health OR depress* OR schizophrenia OR anxiety) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		77
	Obesity	AB ((obesity OR obese OR overweight) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		38
Cochrane Database of Systematic Reviews	Arthritis and musculoskeletal conditions	(arthritis OR musculoskeletal OR osteoporosis OR osteoarthritis OR back pain OR gout) AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords	Year filter (2007–2017), Human, Language filter (English)	89
	Asthma	asthma AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords and		21
	Cancer control	Cancer AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		36
	Cardiovascular health	(cardio* OR cardiac* OR stroke OR thrombo) AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		103
	Dementia	dementia AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		7
	Diabetes	Diabet* AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		41
	Injury prevention and control	(injury prevention OR falls) AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		42
	Mental health	(mental health OR depress* OR anxiety OR suicide OR schizophrenia) AND exercise in Title, Abstract, Keywords and risk factor OR prevention OR management OR treatment in Title, Abstract, Keywords		77
	Obesity	(obesity OR obese OR overweight) AND exercise in Record Title and systematic review OR meta-analysis in Title, Abstract, Keywords and prevention OR risk factor OR treatment OR management in Title, Abstract, Keywords		29
PubMed (with Medline)	Arthritis and musculoskeletal conditions	arthritis(title/abstract) OR osteoporosis(title/abstract) OR back pain(title/abstract) OR osteoarthritis(title/abstract) OR gout(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)	Year filter (2007 – 2017) Human Language filter (English), Systematic reviews or meta-analysis	349
	Asthma	asthma(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		44
	Cancer control	cancer(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		241

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Database	Health priority area	Search terms	Applied filters	Results
	Cardiovascular health	cardiac*(title/abstract) OR cardio*(title/abstract) OR stroke(title/abstract) OR thrombo*(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		328
	Dementia	dementia(title/abstract) OR Alzheimer's (title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		51
	Diabetes	diabet*(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		233
	Injury prevention and control	injury prevention(title/abstract) OR fall(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		87
	Mental health	mental health(title/abstract) OR depressi*(title/abstract) OR anxiety(title/abstract) OR suicide(title/abstract) OR schizophrenia(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		317
	Obesity	obesity(title/abstract) OR obese(title/abstract) OR overweight(title/abstract) AND exercise (title/abstract) AND (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis) AND Review (ptyp)		229
SPORTDiscus	Arthritis and musculoskeletal conditions	AB ((arthritis OR musculoskeletal OR osteoporosis OR osteoarthritis OR back pain OR gout) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)	Year filter (2007–2017) Human Language filter (English) Journal article Peer-reviewed	85
	Asthma	AB ((asthma) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		1
	Cancer control	AB ((cancer) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		24
	Cardiovascular health	AB ((cardio* OR cardiac* OR stroke OR thrombo*) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		48
	Dementia	AB ((dementia) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		1
	Diabetes	AB ((diab*) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		13
	Injury prevention and control	AB ((injury prevention OR fall) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		36
	Mental health	AB ((mental health OR depress* OR schizophrenia OR anxiety) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		31
	Obesity	AB ((obesity OR obese OR overweight) AND exercise) AND AB (prevention OR risk factor OR treatment OR management) AND (systematic review OR meta-analysis)		14



Appendix C: Summary of included reviews and effect of exercise on disease development, treatment, mortality, and secondary clinical outcomes

National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Arthritis and musculoskeletal conditions						
Osteoarthritis	Bartels et al. ¹⁰	Cochrane review of 13 RCTs to evaluate the effects of aquatic exercise for people with knee and/or hip osteoarthritis compared to no intervention.	—	Aquatic exercise has short-term, and clinically relevant effects on patient-reported pain, disability, and QOL.	—	Improvements in disability and QOL.
	Fransen et al. ¹³	Cochrane review of 54 RCTs to evaluate land-based therapeutic exercise in patients with knee OA.	—	The short-term benefit that is sustained for at least 2–6 months after cessation of formal treatment in terms of reduced knee pain, and improvement in physical function.	—	—
	Fransen et al. ¹⁴	Cochrane review of 10 RCTs to evaluate the land-based therapeutic exercise is beneficial for people with hip OA.	—	Land-based therapeutic exercise programs can reduce pain and improve physical function among people with symptomatic hip OA.	—	—
	Waller et al. ¹⁹	Systematic review and meta-analysis of 11 studies to evaluate the effect of therapeutic aquatic exercise on symptoms and functioning of patients with lower limb OA.	—	Benefit on symptoms associated with lower limb OA such as pain.	—	Self-reported improved functioning and QOL.
Rheumatoid arthritis	Baillet et al. ⁹	Systematic review and meta-analysis of 14 RCTs to evaluate the efficacy of aerobic exercises in RA on QOL, function, and clinical and radiologic outcomes.	—	Aerobic and resistance exercise training programs consistently improve the aerobic capacity, muscle strength, and self-reported functional ability in patients with RA.	—	Exercise improved the post-intervention QOL and pain. Exercise appears to be safe in this population.
	Cairns et al. ¹¹	Systematic review of 18 RCTs examining the effects of dynamic exercise in rheumatoid arthritis.	—	Improvement in muscle strength, physical function, and aerobic capacity with dynamic exercise. Improvements in disease activity measures and hip bone mineral density were evident.	—	No studies reported worse outcomes for function, disease activity, or aerobic capacity with dynamic exercise. Exercise needs to be tailored for the individual.

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Lower back pain	Hurkmans et al. ¹⁶	Cochrane review of eight RCT's examining the effects of dynamic exercise programs in patients with rheumatoid arthritis.	—	—	—	Positive effect on aerobic capacity and muscle strength.
	Choi et al. ¹²	Cochrane review of 13 studies to investigate the effectiveness of exercises for preventing new episodes of low-back pain or low-back pain-associated disability.	—	Post-treatment exercise programs can prevent recurrences but conflicting evidence was found for treatment exercise.	—	—
	Oesch et al. ¹⁸	Systematic review and a meta-analysis of 23 RCTs to determine whether exercise is more effective than usual care to reduce work disability in patients with nonacute, nonspecific low back pain, and if so, to explore which type of exercise is most effective.	—	A statistically significant effect in favor of exercise on work disability in nonspecific lower back pain was found in the longer term. No conclusions can be made in relation to exercise type.	—	—
Osteoporosis	Nikander et al. ¹⁷	A systematic review and a meta-analysis of 28 RCTs to evaluate the effects of long-term supervised exercise (≥ 6 months) on estimates of lower-extremity bone strength from childhood to older age.	—	Weight-bearing physical activity increases bone strength in children; however, insufficient evidence supported this in adults.	—	—
	Howe et al. ¹⁵	Cochrane review of 43 RCTs to examine the effectiveness of exercise interventions in preventing bone loss and fractures in postmenopausal women.	—	The most effective type of exercise intervention on bone mineral density (BMD) for the neck of femur appears to be non-weight-bearing high-force exercise such as progressive resistance strength training for the lower limbs. The most effective intervention for BMD at the spine was combination exercise programs.	—	—

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Asthma	Beggs et al. ²⁰	Cochrane review of eight RCTS to examine the effectiveness of swimming training as an intervention for children (under 18) with asthma.	—	There was no effect on numbers of fractures. No statistically significant effects were seen in studies comparing swimming training with usual care of another physical activity for asthma control, asthma exacerbations, or use of corticosteroids for asthma when compared with usual care or another physical activity. Improved exercise capacity (VO ₂ max) and evidence in support of an improvement in lung function. There were no adverse effects on asthma control and swimming training is well tolerated. Physical activity showed marked improvement in cardiopulmonary fitness (maximum O ₂ uptake). There was no statistically significant difference for FEV ₁ , FVC, or minute ventilation. Is well tolerated. No clear differences found between water-based exercise and comparative treatments. High risk of bias.	—	No statistically significant effects of swimming training when compared with usual care or other physical activity for QOL.
	Carson et al. ²¹	Cochrane review of 21 randomized control trials assessing the effect of physical training on the respiratory and general health of people with asthma.	—	Physical activity showed marked improvement in cardiopulmonary fitness (maximum O ₂ uptake). There was no statistically significant difference for FEV ₁ , FVC, or minute ventilation. Is well tolerated. No clear differences found between water-based exercise and comparative treatments. High risk of bias.	—	Physical training improves QOL.
	Grande et al. ²⁴	Cochrane review of three randomized control trials analyzing the effectiveness and safety of water-based exercise for adults with asthma.	—	No clear differences found between water-based exercise and comparative treatments. High risk of bias.	—	—
	Wanrooji et al. ²⁵	Systematic review of 29 randomized control trials assessing the effect of exercise training on children with asthma.	—	Individually tailored exercise programs improve cardiorespiratory fitness and have the potential to improve EIB in children with asthma.	—	—

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Contd...	National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
					Exercise has minimal impact on lung function in asthmatic children.		
			An effective exercise training program for children consists of a personalized program, duration of at least 3 months at least twice per week for 60 minutes.				
		Eichenberger et al. ²³	Systematic review and meta-analysis of 67 trials (23 RCT, 17 CT, 27 NCT) to explore the effects of exercise training on airway hyper-reactivity in asthma.	—	Exercise was shown to improve asthma symptoms, exercise capacity, bronchial hyper-responsiveness, exercise-induced bronchospasm, and FEV1.	—	Exercise significantly improves QOL in asthmatics.
					There was no significant difference between exercise and control groups for PEF.		
					The optimum training volume needs further investigation; a higher training volume or frequency also has a negative impact on QOL despite improving exercise capacity.		
		Crosbie ²²	A systematic review of 16 RCTs exploring the effects of physical training in children with asthma on pulmonary function, aerobic capacity, and health-related QOL.	—	Exercise training does not improve pulmonary function but does increase aerobic capacity.	—	Exercise does improve health-related QOL; however, further RCTs are required to verify these findings.
	Cancer control						
	Prostate cancer	Baumann et al. ²⁶	A systematic review of 25 RCTs examining the effect of clinical exercise interventions in prostate cancer patients.	—		—	Incontinence, fitness, fatigue, body constitution, and QOL can be improved with exercise.
		Bourke et al. ²⁸	A systematic review and meta-analysis of 16 RCTs looking at exercise for men with prostate cancer.	—		—	Exercise improves QOL, fatigue, and submaximal fitness.
		Keogh et al. ³⁵	A systematic review of 12 trials examining the effect of exercise for prostate cancer patients.	—		—	Exercise improves muscular strength, aerobic endurance, QOL, and fatigue.

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Breast cancer	Bicego et al. ²⁷	A systematic review of nine RCTs examining the effect of exercise on QOL in women living with breast cancer.	—	—	—	Exercise improves QOL.
	Monnikhof et al. ³⁷	A systematic review of 48 studies evaluating the effects of exercise on breast cancer.	Inverse relationship between physical activity and post-menopausal breast cancer with risk reductions ranging from 20 to 80%. For premenopausal breast cancer, evidence was much weaker.	—	—	—
	Furmaniak et al. ³²	A Cochrane review of 32 RCTs looking at the exercise for women receiving adjunct therapy for breast cancer.	—	—	—	Exercise probably improves fitness and slightly reduces fatigue. May lead to little or no improvement on QOL. May slightly improve cognitive function.
Cancer (all)	Buffart et al. ²⁹	A meta-analysis of 34 RCTs looking at the effects and moderators of exercise on QOL and physical function in patients with cancer.	—	—	—	Exercise improves QOL and physical function in patients with cancer.
	Cramp et al. ³¹	A Cochrane review of 56 RCTs looking at the effect of exercise for the management of cancer-related fatigue in adults.	—	—	—	Aerobic exercise is beneficial for individuals with cancer-related fatigue during and post-cancer therapy, specifically those with solid tumors.
	Gerritsen et al. ³³	A systematic review and meta-analysis of 16 RCTs looking at the effects of exercise on QOL in patients with cancer.	—	—	—	Exercise improves QOL in patients with cancer.
	Mishra et al. ³⁶	A Cochrane review of 40 trials examining exercise interventions on health-related QOL in cancer survivors.	—	—	—	Exercise had a positive effect on health-related QOL.
	Winzer et al. ³⁸	A systematic review of nine trials examining physical activity and cancer prevention.	—	Exercise has an effect on improving concentrations of several biomarkers implicated in breast and colon cancer pathways.	—	—

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Colorectal cancer	Cramer et al. ³⁰	A systematic review and meta-analysis of five RCTs examining the effect of exercise interventions for colorectal cancer patients.	—	In breast cancer survivors, exercise had a small to moderate effect on improving some biomarkers associated with prognosis.	No reported data on survival rates.	Short-term improvements in physical fitness after aerobic exercise.
Lung cancer	Granger et al. ³⁴	A systematic review of 16 trials examining exercise as an intervention to improve exercise capacity and health-related QOL for patients with non-small cell lung cancer.	—	—	—	Exercise is associated with improvements in QOL and exercise capacity.
Cardiovascular health	Heart failure Adsett et al. ³⁹	A systematic review and meta-analysis of eight studies exploring the effect of aquatic exercise and stable heart failure.	—	—	—	In those with heart failure, aquatic exercise can improve exercise capacity, muscle strength, and QOL similar to land-based training programs. This form of exercise may provide a safe and effective alternative for those unable to participate in traditional exercise programs.
Lewinter et al. ⁴²	A meta-analysis of 46 RCTs examining the effect of exercise-based cardiac rehabilitation (EBCR) in patients with heart failure.	—	—	EBCR has no effect on overall all-cause mortality.	EBCR is associated with improvements in exercise capacity and hospital admissions over a minimum of 6 months.	
Taylor et al. ⁴⁵	A Cochrane review of 33 RCTs examining the effects of exercise-based rehabilitation for heart failure.	—	—	No significant improvement on short-term all-cause mortality; however, some evidence may reduce mortality in the longer term.	Benefits of exercise-based rehabilitation include reduction in hospital admissions due to HF and improvements in health-related QOL.	
No evidence to suggest training causes harm.	—	—	—	—	—	No evidence to suggest training causes harm.

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Coronary heart disease	Davies et al. ⁴¹ Anderson et al. ⁴⁰	A Cochrane review of 19 RCTs examining the effect of exercise training for systolic heart failure. A Cochrane review of 63 RCTs looking at the effect of exercise-based rehabilitation for CHD.	—	—	— Exercise-based cardiac rehabilitation reduces CV mortality when compared with no exercise. There was no reduction with total mortality.	Exercise training reduces heart failure-related hospital admissions and improves QOL. Reduced risk of hospital admissions with cardiac rehabilitation. No significant impact on the risk of MI.
Atrial fibrillation	Risom et al. ⁴³	A Cochrane review of six RCTs examining the effect of exercise-based cardiac rehabilitation for adults with atrial fibrillation.	—	—	No clear evidence of benefit for all-cause mortality.	No clinically relevant effect on health-related QOL.
Stroke	Saunders et al. ⁴⁴	A Cochrane review of 58 RCTs examining the effect of physical fitness training for stroke patients.	—	Cardiorespiratory training and to a less extent mixed training reduce disability during or after usual stroke care. There is insufficient evidence to support resistance training.	—	—
Dementia Vascular dementia	Aarsland et al. ⁴⁶	Systematic review and meta-analysis of 24 studies examining whether physical activity is a potential preventative factor for vascular dementia.	Evidence supporting a reduced risk of vascular dementia in those who are physically active.	—	—	—
Dementia	Barreto et al. ⁴⁷	A systematic review and meta-analysis of 20 studies looking at the effect of exercise training in the management of behavioral and psychological symptoms in people with dementia.	—	—	Exercise had no effect on mortality.	Exercise reduced depression levels.
	Forbes et al. ⁴⁸	A Cochrane review of 17 studies assessing the effectiveness of exercise programs for people with dementia.	—	No clear evidence of benefit from exercise on cognitive functioning.	—	Benefit of exercise on the ability to perform ADLs.

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Contd...	Groot et al. ⁴⁹	A meta-analysis of 18 randomized controlled trials examining the effect of physical activity on cognitive function in patients with dementia.	—	No clear evidence of benefit on neuropsychiatric symptoms. Physical activity positively influences cognitive function in patients with dementia independent of the clinical diagnosis (Alzheimer's dementia vs other dementia).	—	—
	Laver et al. ⁵⁰	A systematic review of 23 studies to assess the effectiveness of interventions to delay decline in people with dementia.	—	Exercise delays cognitive decline in patients with dementia.	—	Exercise improves functional performance and limits cognitive decline in those with dementia.
	Law et al. ⁵¹	A systematic review of eight studies assessing the effects of combined cognitive and exercise interventions on cognition in older adults with and without cognitive impairment.	—	Combined cognitive and exercise training can be effective for improving the cognitive functions and functional status of older adults with and without cognitive impairment. However, limited evidence can be found in populations with cognitive impairment where the evaluation included an active control group.	—	—
	Littbrand et al. ⁵²	A systematic review of 10 studies examining the applicability and effects of physical exercise on physical and cognitive functions and ADLs among people with dementia.	—	Unclear whether exercise can improve cognitive function due to low methodological data.	—	Evidence that exercise improves walking performance and reduces decline in ADLs.
	Ohman et al. ⁵³	A systematic review of 22 RCTs assessing the effect of physical exercise on cognitive function in older adults with dementia and mild cognitive impairment (MCI).	—	Exercise in subjects with MCI to improve global cognition, executive function, and attention. Inconsistent results among those with dementia.	—	—
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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Contd...	Pitkala et al. ⁵⁴	A systematic review of 20 RCTs examining the efficacy of physical exercise interventions on mobility and physical functioning in older people with dementia.	—	—	—	Intensive physical rehabilitation enhances mobility and, when improved over an extended period, may also improve physical functioning in people with dementia.
Young et al. ⁵⁵	Cochrane review of 12 studies examining whether aerobic exercise improves cognitive function in older people without cognitive impairment.	No evidence that aerobic physical activities have any cognitive benefit in cognitively healthy older adults.	—	—	—	
Diabetes T2DM	Aguilar et al. ⁵⁶	Systematic review and meta-analysis of 23 studies examining the efficacy of interventions that include diet, aerobic and resistance training components for T2DM prevention.	—	Multicomponent lifestyle T2DM prevention interventions that include diet and both aerobic and resistance exercise training are modestly effective in inducing weight loss and improving impaired fasting glucose, glucose tolerance, and dietary and exercise outcomes in at-risk and pre-diabetic adult populations.	—	—
Aune et al. ⁵⁷	Systematic review and dose-response meta-analysis of 81 studies examining the effect of physical activity and the risk of T2DM.	Inverse relationship between physical activity and reducing the risk of T2DM; may be partly mediated by a reduction in adiposity. Reductions in risk are observed with 5–7 hours' activity. Further reductions with higher levels cannot be excluded.	—	—	—	—
Orozco et al. ⁶⁰	Cochrane review of eight trials to determine whether exercise or exercise and diet prevent T2DM.	Exercise plus diet reduced the risk of T2DM.	—	—	—	Exercise plus diet has favorable effects on weight and BMI, waist-to-hip ratios and, waist circumference. However, statistically heterogeneity was very high for these outcomes.
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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Gestational diabetes	Bain et al. ⁵⁸	Cochrane review of 13 studies exploring the effects of diet and exercise interventions for the prevention of gestational diabetes mellitus.	No statistically significant difference found when comparing exercise only with conventional methods or diet only. No clear evidence that women receiving a combined diet and exercise intervention have a decreased risk of GDM.	—	—	Women with GDM receiving a combined diet and exercise program had a reduced risk of preterm birth.
Injury prevention and control	Arnold et al. ⁶¹	A systematic review of 22 studies examining whether exercise is beneficial in reducing the risk of falls in community-dwelling older adults.	No difference in GDM incidence between women receiving additional exercise interventions and routine care.	—	—	—
Falls	El-Khoury et al. ⁶²	A systematic review and meta-analysis of 17 studies examining the effect of fall prevention exercise programs on fall-induced injuries in community-dwelling older adults.	Falls risk can be reduced with exercise interventions in community-dwelling older adults. Programs longer than 6 months are more likely to reduce the number and rate of falls. Exercise has an effect on the prevention of falls. It also seems to prevent injuries caused by falls including the most severe ones.	-	-	-
Kendrick et al. ⁶³	A Cochrane review of 30 studies investigating the effects of exercise in reducing the fear of falling in older people living in the community.	Exercise interventions reduce the fear of falling to a limited extent immediately following the intervention. There is evidence suggesting exercise reduces fear of falling up to 6 months post-intervention.	—	—	—	

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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Contd...						
Injury prevention (Sport)	Sherrington et al. ⁶⁶	Systematic review and meta-analysis of 44 studies examining the effectiveness of exercise for the prevention of falls.	Exercise reduces the rates of falls. Greatest effect is seen with a combination of higher total exercise and challenging balancing exercises.	—	—	—
	Rossler et al. ⁶⁵	Systematic review and meta-analysis of 21 trials examining exercise-based injury prevention in child and adolescent sport.	Beneficial effects of exercise-based injury prevention programs in youth sport. Especially in multi-modal programs.			
	Lauersen et al. ⁶⁴	Systematic review and meta-analysis of 25 RCT's exploring the effectiveness of exercise interventions to prevent sports injuries.	Consistently favorable outcomes for injury prevention in all measures except for stretching. Strength training reduces sporting injuries to less than one-third and overuse injuries are almost halved.			
Mental health						
Depression	Cooney et al. ⁶⁷	Cochrane review of 39 trials examining the effect of exercise for depression.	—	Exercise is more effective than a control intervention for reducing symptoms of depression. However, because of the risk of bias in many trials, the effects may only be small. When compared to psychological or pharmacological therapies, exercise appears to be no more effective.	—	—
	Josefsson et al. ⁷⁴	Meta-analysis and systematic review of 15 studies examining the effect of physical exercise interventions in depressive disorders.	—	Physical exercise as a treatment for depression appears to have a moderate to large effect. Especially in those who are willing, motivated, and physically healthy enough.	—	—
Post-natal depression	Daley et al. ⁶⁸	Systematic review and meta-analysis of five RCTs assessing the effectiveness of exercise in the management of postnatal depression.	—	Due to heterogeneity, it is uncertain whether exercise reduces symptoms of postnatal depression.	—	—
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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Contd...	McCurdy et al. ⁷⁵	A meta-analysis of 16 RCTs exploring the effects of exercise on mild to moderate depressive symptoms in the postpartum period.	—	Light-to-moderate intensity aerobic exercise improves mild-to-moderate depressive symptoms and increases the likelihood that mild-to-moderate depression will resolve.	—	—
Anxiety	De Souza et al. ⁶⁹	A systematic review of 10 studies examining the effects of exercise on anxiety disorders.	—	Aerobic exercise either independently or as an adjunctive therapy was effective in reducing symptoms of anxiety.	—	—
	Herring et al. ⁷²	A systematic review of 40 assessing the effect of exercise training on anxiety symptoms.	—	Exercise training reduces anxiety symptoms among sedentary patients who have a chronic disease.	—	—
	Jayakody et al. ⁷³	A systematic review of eight RCTs examining the effect of exercise for anxiety disorders.	—	Exercise seems to be effective as an adjunct treatment for anxiety disorders but is less effective compared with antidepressant treatment.	—	Interventions that target specific groups or are tailored to the individual seem more effective.
	Mochcovitch et al. ⁷⁶	A systematic review of eight studies assessing the effects of regular physical activity on anxiety symptoms in healthy older adults.	—	No significant difference between aerobic and anaerobic groups.	—	—
	Stonerick et al. ⁷⁷	A systematic review of 12 RCTs examining exercise as a treatment for anxiety.	—	Regular and supervised PA was directly related to a decrease in anxiety symptoms in older adults.	—	—
Schizophrenia	Firth et al. ⁷⁰	Systematic review and meta-analysis of 10 studies examining the effects of aerobic exercise on cognitive function in people with schizophrenia.	—	Suggested benefit of exercise for the treatment of anxiety, greater than placebo. However, most studies had methodological limitations.	—	Exercise improves working memory, social cognition, and attention. Effects on processing speed, verbal and visual memory, and reasoning were not significant.
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National health priority area	Reference	Study summary	Effect of exercise on disease development	Effect of exercise on treatment	Effect of exercise on mortality	Effect of exercise on secondary clinical outcomes (e.g., QOL)
Obesity	Gorczyński et al. ⁷¹	Cochrane review of three RCTs assessing exercise therapy for schizophrenia.	—	Exercise was found to significantly improve negative symptoms of mental state; no absolute effects were found for positive symptoms of mental state.	—	Improvement in physical health. There was no effect on weight or BMI.
Pediatric obesity	Garcia-Hermoso et al. ⁷⁸	A systematic review and meta-analysis of nine RCTs assessing the effects of aerobic plus resistance exercise on body composition-related variables.	—	—	—	Aerobic plus resistance exercise reduced BMI and fat mass but did not have an effect on fat-free mass and waist circumference.
	Kelley et al. ⁸¹	A systematic review and trial sequence meta-analysis of 20 studies examining the effects of exercise and BMI scores in obese children and adolescents.	—	Exercise is associated with improvements in BMI among overweight and obese children and adolescents. Additional studies are required to assess heterogeneity including dose-response studies.	—	—
	Ho et al. ⁷⁹	A systematic review and meta-analysis of 15 studies examining the impact of dietary and exercise interventions on weight change and metabolic outcomes in obese children and adolescents.	—	—	—	Addition of exercise to dietary intervention leads to greater improvements in HDL, fasting glucose, and fasting insulin.
	Kelley et al. ⁸⁰	A systematic review of meta-analysis of two studies exploring the effects of exercise in the treatment of overweight and obese children and adolescents.	—	—	—	Exercise is efficacious in reducing percent body fat in overweight and obese children and adolescents. Insufficient evidence exists to suggest exercise reduces other measures of adiposity (BMI, body weight, central adiposity).
Obesity in adults	Södlerlund et al. ⁸²	A systematic review of 12 trials exploring the effect of physical activity, diet, and behavior modification in the treatment of overweight and obese adults.	—	The treatment of obese and overweight adults with exercise alone cannot be expected to result in substantial weight loss. It should be combined with diet and behavior modification therapy for best results.	—	—

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Appendix D: Methodological quality ratings of reviewed papers and interrelated agreement

Reference	Assessing the methodological quality of systematic reviews (AMSTAR)											Total	Percentage
	1	2	3	4	5	6	7	8	9	10	11		
Bartels et al. ¹⁰	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Fransen et al. ¹³	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Fransen et al. ¹⁴	1	1	1	0	1	1	1	1	1	1	0	9	90.9
Waller et al. ¹⁹	0	1	1	0	0	1	1	1	1	0	0	6	63.6
Baillet et al. ⁹	0	1	1	0	0	1	1	1	1	1	0	7	45.5
Cairns et al. ¹¹	0	0	1	0	1	1	1	1	0	0	0	5	81.8
Hurkmans et al. ¹⁶	1	1	1	1	1	1	1	1	1	1	0	10	63.6
Choi et al. ¹²	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Oesch et al. ¹⁸	0	1	1	0	0	1	1	1	1	1	0	7	70.8
Nikander et al. ¹⁷	0	1	1	1	0	1	1	1	0	0	1	7	54.5
Howe et al. ¹⁵	1	1	1	0	1	1	1	1	1	1	0	9	63.3
Beggs et al. ²⁰	1	1	1	1	1	1	1	1	1	1	0	10	90.9
Carson et al. ²¹	1	1	1	1	1	1	1	1	1	1	0	10	90.9
Grande et al. ²⁴	1	1	1	1	1	1	1	1	1	1	0	10	90.0
Wanrooji et al. ²⁵	0	1	1	0	1	1	1	1	1	0	0	6	54.4
Eichenberger et al. ²³	0	1	1	0	0	0	1	1	1	1	1	7	63.6
Crosbie ²²	0	0	1	0	0	1	1	1	1	0	1	6	54.5
Baumann et al. ²⁶	0	1	1	0	0	1	1	1	1	0	1	7	45.5
Bourke et al. ²⁸	0	1	1	1	0	0	1	1	1	1	1	8	45.5
Keogh et al. ³⁵	0	0	1	0	0	0	1	1	1	0	1	5	63.3
Bicego et al. ²⁷	0	0	1	0	0	1	1	1	1	0	0	5	90.9
Monninkhof et al. ³⁷	0	1	1	0	0	1	1	1	1	1	0	7	90.9
Furmaniak et al. ³²	1	1	1	1	1	1	1	1	1	1	0	10	90.9
Buffart et al. ²⁹	1	1	1	1	0	1	1	1	1	1	1	10	90.9
Cramp et al. ³¹	1	1	1	1	1	1	1	1	1	1	0	10	54.5
Gerritsen et al. ³³	0	0	1	0	0	1	1	1	1	0	1	6	63.6
Mishra et al. ³⁶	1	1	1	1	1	1	1	1	1	1	0	10	63.6
Winzer et al. ³⁸	0	1	1	0	0	1	1	1	1	0	1	7	63.6
Cramer et al. ³⁰	0	1	1	0	0	1	1	1	1	1	0	7	63.6
Granger et al. ³⁴	0	1	1	0	0	1	1	1	1	0	1	7	81.8
Adsett et al. ³⁹	0	1	1	0	0	1	1	1	1	0	1	7	81.8
Lewinter et al. ⁴²	0	0	1	0	0	1	1	1	1	0	1	6	81.8
Taylor et al. ⁴⁵	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Davies et al. ⁴¹	1	1	1	0	0	1	1	1	1	1	0	9	90.9
Anderson et al. ⁴⁰	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Risom et al. ⁴³	1	1	1	0	1	1	1	1	1	1	0	9	63.6
Saunders et al. ⁴⁴	1	1	1	1	1	1	1	1	1	1	0	10	72.7
Aarsland et al. ⁴⁶	0	1	0	0	0	1	1	1	1	1	1	7	63.6
Barreto et al. ⁴⁷	0	1	1	0	0	0	1	1	1	1	1	7	63.6
Forbes et al. ⁴⁸	1	1	1	1	1	1	1	1	1	1	0	10	90.9
Groot et al. ⁴⁹	1	1	1	0	1	1	1	1	1	1	0	9	81.8
Laver et al. ⁵⁰	1	1	1	1	0	1	1	1	1	0	1	9	81.8
Law et al. ⁵¹	0	1	1	0	0	1	1	1	0	1	1	7	63.6
Littbrand et al. ⁵²	0	1	1	0	1	1	1	1	0	1	0	7	45.5
Ohman et al. ⁵³	0	1	1	0	0	0	1	1	1	0	0	5	35.4
Pitkala et al. ⁵⁴	0	0	1	0	0	1	1	1	0	0	0	4	90.9
Young et al. ⁵⁵	1	1	1	1	1	1	1	1	1	1	0	10	63.6
Aguiar et al. ⁵⁶	1	0	1	0	0	1	1	1	1	1	1	8	72.7
Aune et al. ⁵⁷	0	0	1	0	1	0	1	1	1	1	1	7	81.8
Orozco et al. ⁶⁰	1	1	1	0	1	1	1	1	1	1	0	9	72.7

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Reference	Assessing the methodological quality of systematic reviews (AMSTAR)											Total	Percentage
	1	2	3	4	5	6	7	8	9	10	11		
Bain et al. ⁵⁸	1	1	1	1	1	1	1	1	1	1	0	10	81.8
Han et al. ⁵⁹	1	1	1	0	1	1	1	1	1	1	0	9	45.5
Arnold et al. ⁶¹	0	1	1	0	0	1	1	1	0	0	0	5	90.9
El-Khoury et al. ⁶²	0	1	1	0	0	1	1	1	1	1	1	8	72.7
Kendrick et al. ⁶³	1	1	1	1	1	1	1	1	1	1	0	10	63.6
Sherrington et al. ⁶⁶	0	1	1	0	0	1	1	1	1	1	1	8	72.7
Rossler et al. ⁶⁵	0	1	1	0	0	1	1	1	1	1	0	7	54.5
Lauersen et al. ⁶⁴	0	1	1	0	0	1	1	1	1	0	1	7	90.9
Cooney et al. ⁶⁷	1	1	1	1	1	1	1	1	1	1	0	10	81.8
Josefsson et al. ⁷⁴	0	0	1	1	0	1	1	1	1	0	0	6	72.7
Daley et al. ⁶⁸	0	1	1	1	0	1	1	1	1	1	1	9	63.6
McCurdy et al. ⁷⁵	0	1	1	1	0	1	1	1	1	0	1	8	72.7
De Souza et al. ⁶⁹	0	1	1	0	0	1	1	1	0	1	1	7	72.7
Herring et al. ⁷²	0	1	1	0	0	0	1	1	1	1	1	7	54.5
Jayakody et al. ⁷³	0	1	1	0	0	1	1	1	1	1	1	8	54.5
Mochcovitch et al. ⁷⁶	0	0	1	0	0	0	1	1	1	1	1	6	81.8
Stonerick et al. ⁷⁷	0	1	1	0	0	0	1	1	0	1	1	6	63.6
Firth et al. ⁷⁰	0	1	1	0	0	1	1	1	1	1	1	8	63.6
Gorczynski et al. ⁷¹	1	1	1	0	1	1	1	1	1	1	0	9	72.7
Garcia-Hermoso et al. ⁷⁸	0	1	1	0	0	1	1	1	1	1	1	8	81.8
Kelley et al. ⁸¹	1	1	1	0	0	1	1	1	1	1	1	9	63.6
Ho et al. ⁷⁹	0	1	1	0	0	1	1	1	1	1	0	7	81.8
Kelley et al. ⁸⁰	1	1	1	0	1	1	1	1	0	1	1	9	36.4
Södlerlund et al. ⁸²	0	0	1	0	0	1	1	1	0	0	0	4	54.5