BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034036
Article Type:	Original research
Date Submitted by the Author:	04-Sep-2019
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Keywords:	PUBLIC HEALTH, SPORTS MEDICINE, PREVENTIVE MEDICINE

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Physical Activity Interventions for Adults who are Visually Impaired: A Systematic Review and Meta-Analysis

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Word Count: 3,765

ABSTRACT

Objectives: Compared with sighted individuals, people with visual impairment have a higher prevalence of chronic conditions and lower levels of physical activity. This review aims to systematically review physical activity interventions for those with a visual impairment and to assess their effectiveness.

Design: A systematic review of articles reporting physical activity interventions in visually impaired individuals was conducted. Medline, EMBASE, The Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL), SPORTDiscus, and the Physiotherapy Evidence Database (PEDro) were searched in August 2018. Meta-analyses were conducted on randomised controlled trials with the same outcome measure.

Setting: Most interventions were conducted in a group setting, with some including an at-home, self-directed component.

Participants: Following identification of a recent systematic review of physical activity interventions in children, our review focused on adults aged 18 years and older with a visual impairment.

Primary and secondary outcome measures: Outcomes included measures of balance, mobility, mental well-being (e.g. quality of life), number of falls, muscle strength, flexibility, and gait.

Results: Eighteen papers from 17 studies met inclusion criteria. Physical activity components include falls prevention and/or balance-based activities, walking, Tai Chi, Alexander Technique, Yoga, dance, aerobics and core stability training. Significant results were reported most commonly in measures of functional capacity (9/17 studies). The

studies identified were generally small and diverse in study design, and risk of bias was high across several categories for most studies.

Conclusions: Physical activity interventions in individuals with visual impairment can have positive results, particularly in physical measures such as mobility and balance. However, when performing a meta-analysis of randomised control trials, the evidence for effectiveness is less clear. More studies with larger sample sizes, stronger designs, broader age ranges and longer follow-up periods are needed.

PROSPERO Registration: PROSPERO CRD42018103638; record available from https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=103638

ARTICLE SUMMARY

Strengths and limitations of this study

- This systematic review was registered a priori and conducted in line with PRISMA and AMSTAR 2 guidelines.
- Six databases were used and a back-reference search of all included studies was conducted.
- No limits on language or year of publication were imposed.
- Risk of bias analysis was conducted independently by two reviewers using the validated Cochrane Collaboration tool.

INTRODUCTION

Physical activity is well established as a prophylactic for many non-communicable diseases including cardiovascular disease, certain cancers, hypertension and type 2 diabetes.(1, 2) In addition to physical health, regular physical activity is also known to benefit psychological wellbeing including a reduction in the risk of depression and anxiety, lowering of stress levels and improving mood.(3, 4) The Centers for Disease Control and Prevention (CDC) recommends at least 150 minutes per week of moderate-intensity aerobic physical activity (or equivalent vigorous activity) for adults (aged 18-64).(5) However, with the global prevalence of insufficient physical activity at nearly 30% in 2016, it is imperative that regular physical activity continues to be promoted and encouraged worldwide.(6) This is important not only in healthy populations, but also in those with diseases and conditions, such as cardiovascular disease and disabilities such as visual impairment. As highlighted by the CDC in the current physical activity guidelines, there is strong evidence that regular physical activity conveys important health benefits for individuals with a disability.(5) However, adults with disabilities are three times more likely to have chronic conditions such as heart disease, diabetes and cancer, and nearly 50% of adults with a disability undertake no leisure time physical activity.(6) More research among those with specific disabilities is needed to address these gaps and improve health outcomes for those with a disability.(7)

In the United States, the five most common functional disabilities are in mobility, cognition, independent living, hearing and vision.(8) In 2015, an estimated 36 million people worldwide were blind (0.49% of the total population, visual acuity worse than 3/60), 217 million (2.95%) had moderate or severe vision impairment (visual acuity worse than 6/18 and 6/60, respectively) and another 189 million (2.57%) had mild vision impairment (visual acuity worse than 6/12). The most common causes of vision impairment include

uncorrected refractive errors, cataracts, age-related macular degeneration, glaucoma, and diabetic retinopathy.(9)

Visual impairment has been shown to detrimentally impact quality of life (10, 11) and to be associated with depression.(12) Also concerning is the fact that studies have shown a higher mortality rate for visually impaired individuals compared with their sighted counterparts, although the underlying reasons are uncertain.(13, 14) Even at the mild end of the impairment spectrum, loss of vision can affect health and wellbeing, for example, through restriction of driving, potentially impacting an individual's sense of autonomy and freedom.(15) Vision impairment has also been shown to be associated with less time spent in moderate-vigorous physical activity in the range of 26-48% compared to sighted individuals.(16-18) One potential reason for this discrepancy is the fear of falling associated with loss of vision and consequent poor balance.(16, 17) For those able to navigate their local environment with the assistance of a guide dog or cane, physical barriers such as uneven, slippery or blocked footpaths can make it difficult to perform adequate physical activity.(19) With the adverse effects that visual impairment can have on wellbeing, and extra challenges those with visual impairments face, it is of upmost importance that physical activity is encouraged in this population, given its beneficial impact on health and wellbeing.

To date, few interventions have included participants with vision impairment. In fact, it is more often the case that visual impairment or blindness are exclusion factors from physical activity interventions. With increasing recognition of the health disparities experienced by people living with disabilities and the lack of research by contrast,(20) it is important to ensure that the principle of inclusiveness is applied so that interventions are designed for those with disabilities. This review aims to systematically review physical activity interventions for those with vision impairment and to assess the effectiveness of the

interventions in improving health-related (physical and mental) outcomes and issues encountered.

METHODS

Eligible studies

This systematic review included peer-reviewed articles reporting on physical activity interventions in visually impaired individuals. The research questions, search strategy and inclusion/exclusion criteria were determined prior to commencing the search and the review was registered on the International Prospective Register of Systematic Reviews (PROSPERO CRD42018103638; record available from https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=103638). Although the initial research plan was to review studies across all age categories, the population of interest was restricted to adults (aged 18 years and over) following the initial search as a recent systematic review among children and adolescents was identified.(21) We included experimental studies focusing on a physical activity intervention or those examining interventions with a clear physical activity component. Controls included individuals not exposed to the intervention or the baseline measurements of participants prior to commencement of the intervention (pre-post study design). Both randomised control trials and non-randomised studies of interventions, including pre-post studies without a comparison group, were included to provide a more complete picture of all the studies in the literature, given the small number expected. Observational studies, reviews, case reports, abstracts, commentaries or other opinion pieces were excluded. No limit on publication date or language of publication was set to ensure broad coverage of the literature. Outcome measures included a range of physical measurements, such as body fat percentage, blood pressure, body mass, waist circumference; physical activity/fitness measures such as flexibility, daily step count, balance and muscle strength and endurance; and wellbeing measures including social and emotional wellbeing and depression.

Sources and Search Strategy

We searched Medline (1946 – August 2018), EMBASE (1947 – August 2018), The Cochrane Library (1993 – August 2018), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (1982 – August 2018), SPORTDiscus (1892 – August 2018), and the Physiotherapy Evidence Database (PEDro) (1929 – August 2018). Back references of all papers included in the review were also searched to identify additional articles. Search terms included those related to blindness and visual impairment (e.g. vision disorders, visually impaired person, glaucoma) and physical activity (e.g. exercise, sports, muscle strength, gait, dancing, and rehabilitation). A targeted search of the Journal of Visual Impairment and Blindness was conducted due to indexing issues discovered during the back-reference search. One article was discovered through this additional search. The final search strategy for Medline is outlined in Supplementary Material 1. This search strategy was adapted for use with the other bibliographic databases in combination with database-specific filters. An initial screen of all abstracts was conducted to identify potentially relevant studies (MA and JS). These studies were then simultaneously and independently reviewed by two reviewers (DD and PASA) to determine eligibility for inclusion in this review, with a third reviewer (DM) enlisted in the case of disagreement.

Data collection

Data were extracted from the eligible papers by JS and summarised into an Excel spreadsheet with the following headings: Author, Year of Publication, Population (including age) and Setting, Visual Conditions, Exclusion Criteria, Study Design, Control Group, Theory (behind the intervention), Type of Physical Activity Intervention, Dose of Intervention (times per week, duration), Delivery (who delivered the intervention), Outcomes, Process Evaluation (e.g. participation, adherence, drop out, feedback),

Results, Other Notes and Funding Sources. We further condensed the extracted data under the headings seen in Tables 1 and 2. Data extraction was checked by KE with agreement achieved on all studies through discussion. Data for one paper written in Farsi was extracted by a collaborator fluent in Farsi.

Analysis

The main characteristics and findings of each study were summarised and tabulated to provide an overview of the literature to date in this area. Where measures were common across RCT studies, a meta-analysis was conducted, using R Foundation for Statistical Computing, version 3.6.0 to estimate the standardised mean difference (SMD) and 95% confidence interval to assess the effectiveness of the interventions. The I^2 was calculated as a measure of heterogeneity between studies. This review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)(22) and A Measurement Tool to Assess Systematic Reviews (AMSTAR2) guidelines (23) (Supplementary 2 and 3). Risk of bias assessment was performed by JS and PASA, using the Cochrane Collaboration's tool for assessing risk of bias. This tool was used to rate each randomised controlled trial (RCT) with a low, high or uncertain risk of bias across six criteria including randomisation, allocation concealment, performance bias, ascertainment bias, incomplete outcome data and selective reporting.(24) For non-randomised studies we considered the risk of bias due to incomplete data and selective reporting.

Patient and Public Involvement

Neither patients nor the public were involved in the design, conduct, reporting or dissemination of this research.

RESULTS

Study selection

A total of 10,112 records were returned, with 6,517 unique record titles and abstracts screened for possible inclusion. Of these, 56 full texts were obtained and reviewed, with 18 papers (from 17 studies) meeting the inclusion criteria (Figure 1). Primary reasons for exclusion were: the studies were conducted in children under the age of 18 (n=19), were not reporting results of a trial of an intervention (e.g. protocol papers) (n=14) and did not include physical activity as a key component of the intervention (n=5). The studies were predominately funded by Government and/or Research Grants (n=9), with funding sources not specified by six studies. One intervention which examined the impact of the Alexander technique (25, 26) was funded by private sources including The Australian Society of Teachers of the Alexander Technique and the FM Alexander Trust (UK), in addition to government and research funding. One intervention was not sponsored.

Study characteristics

The characteristics of the studies are shown in Supplementary Material 4 and summarised in Table 1. Most of the papers (n=14, 78%) were published in the ten years preceding the date of the search (2008-2018). Nine employed a randomised control trial study design, with the remaining eight studies using a pre-post format. Seven interventions were conducted in the United States with the remaining studies conducted in Europe (n= 5), Asia (n=3), and Oceania (n= 2). Except for one study that was published in Farsi, all studies were published in English.

Table 1. Summary of included interventions

	Falls Prevention and Balance Interventions							Other Intervention Types									Mixed
	Campbell (2005)	**Cheung (2008)**	**Kingston (2018)**	**Kovács (2012)**	**Surakka (2008)**	**Surakka (2011)**	**Waterman (2016)**	**Ackley-Holbrook (2016)**	**Chen (2012)**	**Gleeson (2015, 2017)**	**Jeter (2012)**	**Jeter (2015)**	**Larsson (2006)**	**Miszko (2004)**	**Ponchillia (1992)**	**Salari (2013)**	**Hackney (2015)**
Study Design	RCT	RCT	PP	RCT	PP	RCT	RCT	PP	RCT	RCT	PP	RCT	PP	PP	PP	PP	RCT
Sample size	391	50	24	41	27	29	49	21	40	120	10	21	8	10	3	30	32
Mean age (yrs)	84	83	80	69	54	56	81	48	86	75	46	55	52	53	31	22	79
Basis of PA Intervention	Otago	Balance + Strength	Matter Of Balance	Otago	Balance	Balance	Otago	Walking	Tai Chi	Alexander Technique	Yoga	Yoga	Dance	Tai Chi	Aerobics	Core stability	Exp.= Dance Ctrl= FallProof
Delivery mode[a]	Self-directed	Group	Group	Group	Group or mixed	Group	Self-directed	Self-directed	Group	Group	Mixed	Mixed	Group	Mixed	Group	-	Group
Duration	1yr	12wks	4wks	6mths	5-6wks	5-6wks	6mths	8wks	16wks	12wks	8wks	8wks	8wks	8wks	7wks	8wks	10-12wks
Compliance	18%	100%	-	95%	Mean # sessions = 13.5	-	Equivocal	94%	-	100%	-	82% sessions 90% home practice	-	-	-	-	25/32 completed all sessions
Retention	92%	100%	100%	100%	89%	100%	88%	81%	62%	93%	70%	81%	88%	80%	100%	-	78%
Adverse Outcomes	N = 1 moderate injury	None	-	N = 22 falls	-	-	None	N = 2 falls	-	N = 2 deaths, N=1 hospitalisation	-	None	-	None	-	-	-
Results[b]																	
Falls and Balance	Mixed	+	NT	0	DA	NT	0	NT	+	+ (postural sway)	DA	+	~ +	DA	NT	+	+
Functional Capacity	NT	+	DA	+	NT	+	NT	+	+	0	NT	+	~ +	DA	~ +	NT	+
Psych. well-being	NT	NT	NT	NT	DA	NT	0	NT	NT	0	DA	NT	NT	DA	NT	NT	0

[a] Mixed = self-directed sessions in combination with regular group classes or face to face session; Group = group class-based only.

[b] + = statistically significant result in favor of intervention, 0 = no statistically significant change, ~+ = analysis at individual level showing significant change, DA = descriptive analysis only, NT = not tested.

'-' = Not reported

Abbreviations: PP - pre-post; RCT – randomised controlled trial

Participants

There was a total of 906 participants across the 17 interventions, with a mean of 53 and a median of 29 per study. The number of participants per study ranged from three to 391 with 14 studies with 50 or fewer participants. The mean age across all studies was 62 years, with only two (27, 28) examining populations aged younger than 35 years. Approximately two-thirds (70%) of participants were female, with three studies only including women.(27, 29, 30) Participants were recruited through a combination of local advocacy groups, community center listings, and by word-of-mouth in four studies. In eight studies participants were recruited from medical institutions such as hospitals, clinics, private practices and rehabilitation services. In two studies participants were recruited from residential care homes and one recruited participants from a university (recruitment method unknown in two studies).

Visual impairment was defined in several ways with varying levels of detail. Most studies provided cut-points of visual acuity (e.g. 6/24 or worse), while some linked these cut points to those designated by the World Health Organization International Classification of Diseases Codes.(31, 32) Visual conditions identified included age-related conditions such as macular degeneration and cataracts, diabetic retinopathy, glaucoma, corneal scars, and congenital blindness.

Intervention types

Seven studies employed specific falls prevention and/or balance-based physical activity interventions. Of these, three used the Otago exercise program,(30, 33, 34) three used general physical activity training programs aiming to improve balance,(29, 35, 36) and one used the Matter of Balance program.(37, 38) The remaining interventions were based on

other forms of physical activity including walking (n=1),(31) Tai Chi (n=2),(39, 40) Alexander Technique (n=1),(25, 26) Yoga (n=2),(41, 42) dance (n=1),(43) aerobics (n=1) (27) and core stability training (n=1).(28) One study utilised a falls prevention program (FallProof) as a control, comparing to a dance-based intervention program.(32) The interventions were predominately delivered in a group based, face-to-face format with only three being chiefly self-directed with periodic contact from investigators.(31, 33, 34) The interventions ran for an average of 13 weeks (range of four weeks – one year) with three-quarters (n = 13/17, 76%) having a duration of 4 -12 weeks.

Objectives

In general, each intervention aimed to assess the impact of a physical activity program on falls risk or balance, physical health, and/or mental health. Four interventions aimed to compare the physical activity intervention to another program such as a home safety program,(33, 34) fall prevention program,(32) or osteoporosis program.(30) Eight interventions aimed to cater specifically for “older” or “elderly” individuals. One study focused on female athletes.(28) Two studies examined the cost-effectiveness of the intervention.(33, 34)

Outcome measures

As summarised in Table 2, the most common outcomes were measures of balance, reported in 65% of the interventions (Berg Balance Scale [BBS], n = 4; other measures e.g. sensory organisation test [SOT] and one legged stance [OLS], n = 9). Six studies (35%) examined the impact of the intervention of an aspect of mental well-being such as anxiety, depression, or quality of life. Measures of mobility were used in five studies (29%),

most commonly the timed up and go (TUG) test (n=5). Other outcome measures included number of falls (n=4), muscle strength (n=3), flexibility (n=3), gait (n=3), anthropometric measures (n=3), the chair stand test (n=2) and sleep (n=1).

Table 2 Summary of outcome measures

	OUTCOME	Ackley-Holbrook (2016)	Campbell (2005)	Chen (2012)	Cheung (2008)	Gleeson (2015, 2017)	Hackney (2015)	Jeter (2012)	Jeter (2015)	Kingston (2018)	Kovács (2012)	Larsson (2006)	Miszko (2004)	Ponchillia (1992)	Salari (2013)	Surakka (2008)	Surakka (2011)	Waterman (2016)
Balance	Number of Falls		X			X					X							X
	Berg Balance Scale				X		X				X		X					
	Other Balance[a]			X		X	X	X	X			X	X		X	X		
Functional Capacity	Timed Up and Go				X		X			X	X	X						
	Other Mobility[b]									X	X							
	Chair Stand Test				X	X												
	Other Fitness[c]	X				X	X					X		X				
	Muscle strength			X									X	X				
	Flexibility								X					X			X	
Other	Psychological well-being[d]					X	X	X					X			X		X

[a] Including measures of postural sway and stability (Sensory Organisation Test, One Legged Stance, Mean Stride Length, Functional Reach).

[b] Including Performance-oriented mobility assessment and Activity Index

[c] Including six-minute walk test, step count, gait measures.

[d] Including measures of quality of life, anxiety, depression, emotional wellbeing.

Synthesis of Results

Falls or balance related outcomes were measured in 13 studies, with statistically significant results in favor of the intervention observed in seven studies (54%). Although more falls were recorded in the intervention group in the Campbell et al. (2005) study, further analysis showed fewer falls with increasing adherence to the exercise program (p=0.001). Measures of functional capacity were used in 12 studies, with statistically significant results in favor of the intervention observed in nine studies (75%). Psychological well-being was measured in only six studies and no significant results were observed in these outcomes. No paper reported negative results that would suggest the intervention was detrimental to any aspect of health measured. Drop out reasons across all studies included medical problems (n=10), lack of transport or travel time (n=7), dissatisfaction with program (n=1), time (n=2), other (n=3).

Effectiveness of Interventions on PA outcomes

A meta-analysis was conducted where outcome measures were common across RCT interventions, namely for the Timed Up and Go (TUG), Chair Sit Test (CST) and Berg Balance Scale (BBS). Only four studies were able to be included in the meta-analysis and the results are shown in Figure 2. In all instances, the combined results crossed the line of null effect (mean difference = 0) indicating non-significant effects of the interventions on each of the outcome measures. In addition, the wide 95% confidence intervals indicate imprecision across the studies, potentially due to small sample sizes. Heterogeneity was low for the TUG and CST (I^2 = 0% and 22%, respectively) suggesting consistent null findings, however, it was high for the BBS (I^2 = 53%).

Study Quality – Risk of Bias Assessment

The results of the Risk of Bias assessment can be found in Table 3. In general, the randomised controlled trials showed a low risk of bias in randomisation (n=6/9 'low') and allocation concealment (n=6/9 'low'). Risk of attrition bias due to incomplete data was also low in the majority of all studies (n=11/17). Of note, all but one study was categorised as 'unclear' or 'high' risk of reporting bias due to selective outcome reporting. In all pre-post studies it was not possible to determine if all outcomes were reported due to the lack of study protocol or registrations. Of the nine randomised controlled trials, study protocols were unavailable for five, two were missing a priori secondary outcomes, one followed the study protocol, and one deviated from the study protocol.

Table 3. Risk of bias assessment for randomised control trials (RCTs) and pre-post studies

	Risk of bias (High, low, unclear)					
Source	**Randomisation sequence allocation**	**Concealment**	**Performance bias**	**Ascertainment bias**	**Incomplete outcome data**	**Selective reporting**
RCTs						
Campbell et al (2005)	LOW	LOW	UNCLEAR	UNCLEAR	LOW	UNCLEAR
Chen et al (2012)	UNCLEAR	UNCLEAR	LOW	LOW	LOW	UNCLEAR
Cheung et al., (2008)	LOW	LOW	LOW	LOW	LOW	UNCLEAR
Gleeson et al. (2015, 2017)	LOW	LOW	UNCLEAR	LOW	LOW	UNCLEAR
Hackney et al. (2015)	HIGH	HIGH	HIGH	UNCLEAR	LOW	UNCLEAR
Jeter et al (2015)	LOW	LOW	HIGH	LOW	LOW	HIGH
Kovacs et al (2012)	LOW	LOW	UNCLEAR	LOW	LOW	UNCLEAR
Surakka et al (2011)	UNCLEAR	UNCLEAR	HIGH	HIGH	UNCLEAR	UNCLEAR
Waterman et al (2016)	LOW	LOW	HIGH	LOW	LOW	LOW
Pre-post with no comparison group						
Ackley-Holbrook et al (2016)	---	---	---	---	LOW	UNCLEAR
Jeter (2012)	---	---	---	---	HIGH	UNCLEAR
Kingston (2018)	---	---	---	---	UNCLEAR	UNCLEAR
Larsson (2006)	---	---	---	---	LOW	UNCLEAR
Miszko (2004)	---	---	---	---	UNCLEAR	UNCLEAR
Ponchillia (1992)	---	---	---	---	LOW	UNCLEAR
Salari (2013)	---	---	---	---	UNCLEAR	UNCLEAR
Surakka (2008)	---	---	---	---	UNCLEAR	UNCLEAR

--- Not applicable

DISCUSSION

This systematic review sought to summarise the effects of physical activity interventions in adults who are visually impaired. Based on the studies identified, there is evidence that physical activity interventions are beneficial to adults with visual impairment, with positive health benefits observed particularly in outcomes related to functional capacity. However, when focusing on RCTs, where the risk of bias is lower, and examining combined results in a meta-analysis, the evidence for intervention effectiveness is less clear.

This review identified seventeen intervention studies, which represents a considerably small evidence base, particularly in contrast to the size of the problems related to physical inactivity, health conditions and challenges faced by many people with visual impairment. Several characteristics of existing studies have also limited the internal and external validity. First, most studies included very small sample sizes with four presenting descriptive analysis only (did not report inferential statistics) and two reporting results at an individual, rather than group level. Second, there was a substantial imbalance in both gender (70% female participants) and age with all but two studies focused on individuals aged older than 45 years. However, overrepresentation of female participants is common in health interventions and people aged 50 years and older represent 65% of all visually impaired persons worldwide (and 82% of blind persons).(44) Third, more than three-quarters of the studies ran for 12 weeks or less, limiting the ability to assess maintenance of changes observed and effects on outcomes that may take time to change. For example, of the six studies assessing psychological well-being and mental health outcomes, none reported statistically significant improvements. However, promising results were observed in measures of functional capacity, such as mobility and fitness, and balance, even in a relatively short time period of 5-6 weeks.(36) To address these issues future interventions should, where possible, employ an

RCT study design with a priori calculation of participants needed to ensure the study is powered for more robust statistical analysis. If feasible, a longer duration would also be of benefit, particularly in establishing the impact of the interventions on mental health outcomes. Also, a targeted approach to include males and those aged 18-45 years may be appropriate to address the underrepresentation of these demographics in the current literature.

A wide range of physical activities were used by the intervention studies, most of which focused on low-intensity physical activities, such as yoga and Tai Chi, with a strong emphasis on improving balance and stability. Only one study incorporated higher intensity activity in the form of aerobics with “many high-impact (bouncing and jumping) … movements”.(27) However, this study was also the smallest with only three participants, so it is hard to determine its effects. Although the benefits of yoga, Tai Chi and other low-intensity activities have been documented,(45-47) moderate and vigorous physical activity have further health benefits and are generally the primary focus of global physical activity guidelines.(5) The current CDC guidelines recommend a minimum of 150 minutes per week of moderate activity per week (or 75 minutes of vigorous activity) (5) with the evidence on light intensity physical activity not yet conclusive for informing guidelines.(1) Although these guidelines highlight a dose-response relationship whereby more health benefits are gained with an increase in moderate intensity physical activity undertaken, even small increases in physiological capacity / physical activity provide significant reduction in mortality risk.(48, 49) This suggests that future physical activity interventions among those with visual impairment should consider incorporating some physical activity at a moderate intensity or higher, even if only in small doses in older individuals. Although on the surface visual impairment may appear to be a barrier to undertaking moderate or vigorous physical activity, the existence of numerous sports for visually impaired athletes at Paralympic level would suggest otherwise.(50) Even

though few individuals reach this height of athletic ability, it is evident that visually impaired individuals can perform higher intensity activities, evidenced by the feasibility of physical activity trials with walking and aerobics as the intervention.(27, 31) Therefore, development of interventions for moderate and / or vigorous physical activity could form a focus in future work. Moreover, given the increased risk of poorer physical and mental health for those who are visually impaired,(13, 51) it is important to ensure they are given opportunities to undertake physical activity at higher intensities in order to garner the further health benefits.

In terms of delivery mode, studies were predominately group-based, with nine of sixteen (delivery mode unknown in one study) purely delivered in a face-to-face manner, and a further four involving group classes with additional self-directed practice at home. The remaining three studies were of a more self-directed nature with varying levels of investigator involvement including five home visits throughout the year-long study,(33) five home visits (from occupational therapist or peer mentor) and two phone calls over the six month duration,(34) and a single orientation session followed by self-directed activity.(31) Further intervention studies could compare the effectiveness of group-based and self-directed trials to determine the possibility of reducing investigator burden in delivery by increasing self-directed options where possible. This would have the added benefit of incorporating capacity building into the intervention and enabling participants to continue in their new habits post-intervention. Alternatively, the use of already existing programs such as regular community dance classes could be examined as a means of increasing the likelihood of maintaining changes to physical activity behaviors following the intervention. To our knowledge, none of the group-based interventions identified allowed participants to continue in the physical activity following the study as they were all conducted for research purposes only. However,

given the habitual nature physical activity, it is possible highly motivated individuals may have continued to practice in their own homes following instruction during the intervention.

Strengths and limitations

The strengths of this systematic review include incorporating both qualitative and quantitative evidence synthesis, following AMSTAR2 and PRISMA guidelines, and not restricting literature search by publication language and dates. Limitations relate to the studies identified, rather than the review process itself. The studies identified were generally small with diverse study designs and outcomes measured. This made it challenging to determine the effectiveness of the interventions and to identify the aspects that should be retained in subsequent studies. Most studies lasted for a short period of time without intended examination for longer-term maintenance. Finally, the quality assessment showed a high risk of bias across the papers in several categories.

CONCLUSION

Given the higher risk of developing non-communicable diseases for those with visual impairment, it is imperative that sufficient physical activity is undertaken by these individuals to ensure that they benefit from the positive health outcomes. This systematic review illustrates that physical activity interventions in individuals with visual impairment can have positive results, particularly in physical measures such as mobility and balance. However, when performing a meta-analysis of RCTs, the evidence for effectiveness is less clear. More high quality research needs to be conducted in larger groups, with a broader age focus and

over longer periods of time to enable the optimisation of further interventions. Additionally, future studies need to incorporate interventions that equip the participants with skills and confidence to sustain their new physical activity behaviors post-intervention. Finally, more research is required into the feasibility of interventions that address the need for moderate and vigorous physical activity, which unlock even more health benefits compared to the low intensity activities reported in this systematic review.

AUTHOR CONTRIBUTIONS

JS, DM, MA, DD were involved in study design. All authors made substantial contributions to the acquisition, analysis and/or interpretation of the data and to drafting and revising the work.

ACKNOWLEDGEMENTS

The authors wish to thank Dr Javad Koohsari, from Waseda University, Japan, for helping with translation and data extraction from a study published in Farsi.

FUNDING

The work was supported by a Sydney Research Accelerator (SOAR) prize awarded to Ding. Ding is funded by a National Heart Foundation Future Leader Fellowship.

COMPETING INTERESTS

None declared.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article or uploaded as supplementary information.

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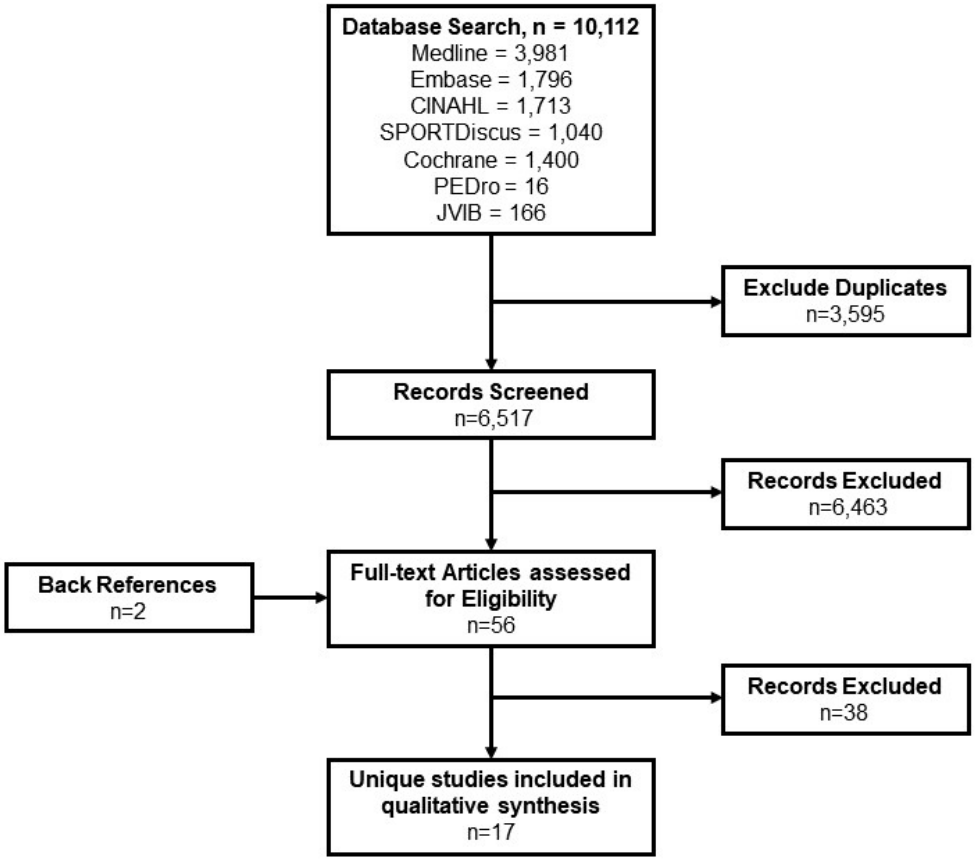
FIGURE LEGENDS

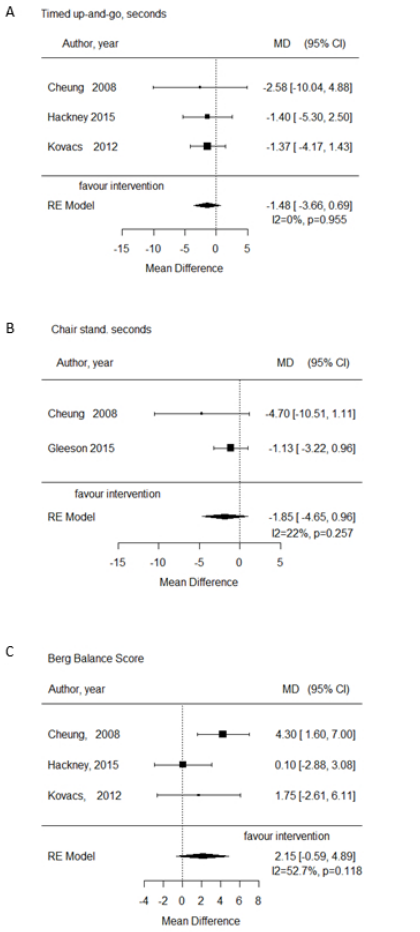
Figure 1 PRISMA FlowChart

Figure 2 Forest Plots from Meta Analyses. A) Timed Up and Go. B) Chair Stand Test. C) Berg Balance Scale. Abbreviations; CI = confidence interval, MD = mean difference, RE = Random Effects



PRISMA FlowChart

190x219mm (96 x 96 DPI)



A. Timed Up and Go. B . Chair Stand Test. C. Berg Balance Scale

Forest Plots from Meta Analyses. A) Timed Up and Go. B) Chair Stand Test. C) Berg Balance Scale. Abbreviations; CI = confidence interval, MD = mean difference, RE = Random Effects

Supplementary Material 1. Search strategy for Medline

Vision Related Terms	Physical Activity Terms
MeSH TERMS	
Vision Disorders	Exercise
Visually Impaired Persons	Exercise therapy
Glaucoma	Sports
Retinal Diseases	Tai ji
Cataract	Yoga
	Dancing
	Postural Balance
	Posture
	Muscle Strength
	Gait
	Mobility Limitation
	Exercise movement techniques
	Walking
	Rehabilitation
	Dance therapy
	Occupational therapy
	Recreation therapy
KEYWORD SEARCH TERMS	
Vision*or visual*or eye*or sight adj3 (impair* or loss or disorder* or disease* or disabl*))	Exercise
Blindness	Physical* adj3 activ*
	Danc*

Vision related terms combined with “OR”.

Physical activity terms combined with “OR”.

Vision related and physical activity terms combined with “AND”.

PRISMA 2009 Checklist

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

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-15
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	17-18
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Fig 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Fig 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	18
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	19-22
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	21-22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	22
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	23

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

1. Did the research questions and inclusion criteria for the review include the components of PICO?

For Yes:
- ☑ Population
- ☑ Intervention
- ☑ Comparator group
- ☑ Outcome

Optional (recommended)
- ☐ Timeframe for follow-up

- ☑ Yes
- ☐ No

2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?

For Partial Yes:
The authors state that they had a written protocol or guide that included ALL the following:
- ☑ review question(s)
- ☑ a search strategy
- ☑ inclusion/exclusion criteria
- ☑ a risk of bias assessment

For Yes:
As for partial yes, plus the protocol should be registered and should also have specified:
- ☐ a meta-analysis/synthesis plan, if appropriate, *and*
- ☐ a plan for investigating causes of heterogeneity
- ☐ justification for any deviations from the protocol

- ☐ Yes
- ☑ Partial Yes
- ☐ No

3. Did the review authors explain their selection of the study designs for inclusion in the review?

For Yes, the review should satisfy ONE of the following:
- ☐ *Explanation for* including only RCTs
- ☐ OR *Explanation for* including only NRSI
- ☑ OR *Explanation for* including both RCTs and NRSI

- ☑ Yes
- ☐ No

4. Did the review authors use a comprehensive literature search strategy?

For Partial Yes (all the following):
- ☑ searched at least 2 databases (relevant to research question)
- ☑ provided key word and/or search strategy
- ☑ justified publication restrictions (e.g. language)

For Yes, should also have (all the following):
- ☑ searched the reference lists / bibliographies of included studies
- ☑ searched trial/study registries
- ☑ included/consulted content experts in the field
- ☑ where relevant, searched for grey literature
- ☑ conducted search within 24 months of completion of the review

- ☑ Yes
- ☐ Partial Yes
- ☐ No

5. Did the review authors perform study selection in duplicate?

For Yes, either ONE of the following:
- ☑ at least two reviewers independently agreed on selection of eligible studies and achieved consensus on which studies to include
- ☐ OR two reviewers selected a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder selected by one reviewer.

- ☑ Yes
- ☐ No

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

6. Did the review authors perform data extraction in duplicate?

For Yes, either ONE of the following:

- ☑ at least two reviewers achieved consensus on which data to extract from included studies
- ☐ OR two reviewers extracted data from a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder extracted by one reviewer.

☑ Yes
☐ No

7. Did the review authors provide a list of excluded studies and justify the exclusions?

For Partial Yes:

- ☐ provided a list of all potentially relevant studies that were read in full-text form but excluded from the review

For Yes, must also have:

- ☐ Justified the exclusion from the review of each potentially relevant study

☐ Yes
☐ Partial Yes
☑ No

8. Did the review authors describe the included studies in adequate detail?

For Partial Yes (ALL the following):

- ☑ described populations
- ☑ described interventions
- ☑ described comparators
- ☑ described outcomes
- ☑ described research designs

For Yes, should also have ALL the following:

- ☑ described population in detail
- ☑ described intervention in detail (including doses where relevant)
- ☑ described comparator in detail (including doses where relevant)
- ☑ described study's setting
- ☑ timeframe for follow-up

☑ Yes
☐ Partial Yes
☐ No

9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?

RCTs

For Partial Yes, must have assessed RoB from

- ☑ unconcealed allocation, *and*
- ☑ lack of blinding of patients and assessors when assessing outcomes (unnecessary for objective outcomes such as all-cause mortality)

For Yes, must also have assessed RoB from:

- ☑ allocation sequence that was not truly random, *and*
- ☑ selection of the reported result from among multiple measurements or analyses of a specified outcome

☑ Yes
☐ Partial Yes
☐ No
☐ Includes only NRSI

NRSI

For Partial Yes, must have assessed RoB:

- ☑ from confounding, *and*
- ☑ from selection bias

For Yes, must also have assessed RoB:

- ☑ methods used to ascertain exposures and outcomes, *and*
- ☑ selection of the reported result from among multiple measurements or analyses of a specified outcome

☑ Yes
☐ Partial Yes
☐ No
☐ Includes only RCTs

10. Did the review authors report on the sources of funding for the studies included in the review?

For Yes

- ☑ Must have reported on the sources of funding for individual studies included in the review. Note: Reporting that the reviewers looked for this information but it was not reported by study authors also qualifies

☑ Yes
☐ No

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?

RCTs

For Yes:

- ☑ The authors justified combining the data in a meta-analysis
  - ☑ AND they used an appropriate weighted technique to combine study results and adjusted for heterogeneity if present.
  - ☑ AND investigated the causes of any heterogeneity

☑ Yes
☐ No
☐ No meta-analysis conducted

For NRSI

For Yes:

- ☐ The authors justified combining the data in a meta-analysis
  - ☐ AND they used an appropriate weighted technique to combine study results, adjusting for heterogeneity if present
  - ☐ AND they statistically combined effect estimates from NRSI that were adjusted for confounding, rather than combining raw data, or justified combining raw data when adjusted effect estimates were not available
  - ☐ AND they reported separate summary estimates for RCTs and NRSI separately when both were included in the review

☐ Yes
☐ No
☑ No meta-analysis conducted

12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?

For Yes:

- ☐ included only low risk of bias RCTs
- ☑ OR, if the pooled estimate was based on RCTs and/or NRSI at variable RoB, the authors performed analyses to investigate possible impact of RoB on summary estimates of effect.

☑ Yes
☐ No
☐ No meta-analysis conducted

13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?

For Yes:

- ☐ included only low risk of bias RCTs
- ☑ OR, if RCTs with moderate or high RoB, or NRSI were included the review provided a discussion of the likely impact of RoB on the results

☑ Yes
☐ No

14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?

For Yes:

- ☐ There was no significant heterogeneity in the results
- ☑ OR if heterogeneity was present the authors performed an investigation of sources of any heterogeneity in the results and discussed the impact of this on the results of the review

☑ Yes
☐ No

15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?

For Yes:

- ☑ performed graphical or statistical tests for publication bias and discussed the likelihood and magnitude of impact of publication bias

☑ Yes
☐ No
☐ No meta-analysis conducted

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

For Yes:

- ☑ The authors reported no competing interests OR
- ☐ The authors described their funding sources and how they managed potential conflicts of interest

☑ Yes
☐ No

To cite this tool: Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017 Sep 21;358:j4008.

Supplementary Material 4. Characteristics of included intervention studies

First author, year (setting)	Study Design	Participants	Intervention (Description and Dose)	Control	Outcomes	Results
Ackley-Holbrook, 2016 (USA)	Pre Post	Severe VI or blindness. Recruited through advocacy organizations, online discussion groups and communities, word-of-mouth. Aged ≥ 18yrs. Mean age = 47.9 ± 11.5 yrs. % Males = UNK n = 21	Walking program; 8 weeks, increasing daily step count by 1000 above baseline, progressively higher targets every 2 weeks	Baseline step count	Daily step count (by pedometer), resting heart rate, blood pressure, body mass, % body fat, waist circumference, lipids	Significant increase in steps per day; (baseline 4925 ± 2233 v post 8772 ± 2916, p<0.01). No significant differences in other measures. Reported improvements in cardiovascular endurance and productivity (93%), mood and mental health (73%), outlook on life, self confidence and functional mobility (67%).
Campbell, 2005 (NZ)	RCT	Visual acuity of 6/24 or worse. Recruited via register for the blind, hospital outpatient clinics, private ophthalmology practice. Living in community. Aged ≥75. Mean age = 83.6 ± 4.8 yrs % Males = 32% n = 391	Four groups; 1) Otago exercise program (Muscle strengthening and balance retraining exercises that progress in difficulty) and walking plan; 5 home visits from a physiotherapist, 3 X 30min per week of exercises plus walking twice a week. n=97 2) Home safety program (Home visit to identify hazards and provision of recommendations to prevent falls). n=100 3) Exercise and home safety program. n=98 4) Control (social visits). n = 96	Two social visits during the first six months	Number of falls and fall related injuries	15% more falls observed in the exercise program (incidence rate ratio = 0.59 [CI 0.42-0.83] v 1.15 [CI 0.82-1.61], however a higher level of adherence led to fewer falls (p=0.001). 41% fewer falls in the home safety program. One year of follow up.
Chen, 2012 (HK)	RCT	Low vision (6/18 - 3/60) and blind (3/60 or worse). Living in a residential care home. Aged ≥ 70. Mean age = 85.5 ± 6.9 yrs (experimental) and 82.9 ± 7.5 yrs (control) % Males = UNK n = 40	Modified 8-form Yang style Tai Chi, emphasizing multi-directional weight shifting, head and trunk rotation and awareness of body alignment; 1.5 hours, 3 times a week, for 16 weeks. n = 21 in intervention	Music percussion activity (djembe i.e. drumming)	Knee proprioception, muscle strength (in knee extensors and flexors), balance	Experimental group showed significant improvements in knee proprioception (percentage change of absolute angle error = -25.9 ± 28.8% v 4.2 ± 30.7%, p=0.032) and balance control (greater percentage change in visual ratio (58.1 ± 41.9% v -1.6 ± 29.4%, p=0.006) and vestibular ratio (32.5 ± 40.2% v -17.8 ± 56.8%, p=0.048). Intention to treat analysis.
Cheung, 2008 (HK)	RCT	No light perception or VI of 6/120 or worse in better eye with corrective device. Living in care and attention homes. Aged ≥ 65. Mean age = 83 ± 4.7 yrs (experimental) and 84 ± 6.5 yrs (control) % Males = 0%	Structured, individually tailored exercise program designed by a physiotherapist, including warm up, lower limb strengthening exercises (increasing in repetitions and weights), balance exercises. Plus routine group physical activity. 3 X 45 min per week, for 12 weeks n = 27 in intervention.	Routine group physical activity only in care home.	Balance and muscle strength.	Significant improvements in BBS (9.4%, p<0.000), TUG (decrease of 4.7 sec, p<0.0003) and CST (decrease of 2.35 sec, p=0.047)

		n = 50				
Gleeson, 2015 (AUS)	RCT	Participants recruited from Guide Dogs Australia. Aged ≥ 50. Mean age = 75 ± 11 yrs. % Males = 29% n = 120	Alexander Technique, 1 X 30 min lesson per week, for 12 weeks, plus usual care. n = 60 in intervention.	Usual care from Guide Dogs Australia.	Short Physical Performance Battery (sit-to-stand, 4m walk test, standing balance test). Postural sway tests, maximal balance range and number of falls.	No statistically significant improvements in primary outcomes at 3 or 12 months between groups. Intervention group reduced postural sway on a firm surface (eyes open) at 3mths (-29.59mm, P<0.01).
Gleeson, 2017 (AUS)	RCT	As per Gleeson 2015	As per Gleeson 2015,	As per Gleeson 2015	Social and emotional wellbeing	No statistically significant improvements at 3 or 12 months. Emotional subscale approached significance (p=0.06) in favor of intervention at three mths.
Hackney, 2015 (USA)	RCT	VI in range 20/30 – 20/632. Recruited from Medical Centre, Senior Independent Living communities, community senior centres. Mean age = 79.3 ± 11 yrs % Males = 47% n = 32	Adapted Tango Classes, 2 X 1.5 hours per week, for 10-12 weeks (total 30 hours). n = 14 Tango intervention.	FallProof Program	Balance, Mobility, Gait speed and quality-of-life.	Tango and FallProof groups showed improvements on BBS (p=0.001). SOT scores improved by 14% in Tango group and 22% in FallProof. Tango group significantly improved on 6MWT (p=0.016), cognitive-TUG(p=0.03) and gait (p<0.001). Last observation carried forward analysis.
Jeter, 2012 (USA)	Pre Post	Visual field <20 deg and/or visual acuity < 20/200. Recruited from Low Vision Clinic of tertiary hospital and local community based listings. Mean age = 46 ± 12 yrs. % Males = 30% n = 10	Ashtanga-Based Yoga (AYT), 1 X orientation session, 1 class per week and 2 sessions per week at home, for 8 weeks.	None	Sleep, anxiety, depression, stress, balance, respiratory rate, mindfulness, balance	Improvements observed in all pre-post measures (descriptive analysis only). Exit surveys showed 5/8 reported reduced stress, 3/8 reported improved sleep. 7/8 reported improved relaxation and focus. 8/8 expressed an interest in a yoga program like this in the future.8/8 subjects were extremely or mostly satisfied with program.
Jeter 2015 (USA)	RCT	Corrected visual acuity worse than 20/200 and/or visual field less than 20 deg in diameter (legal blindness). Recruited from Low Vision Clinic of tertiary hospital. Mean age = 55 ± 17 yrs (experimental) and 55 ± 10 yrs (control) % Males = 29% n = 21	Ashtanga-Based Yoga (AYT), 1 X orientation session, 1 class per week and 2 sessions per week at home, for 8 weeks. n = 11 in intervention	Waitlist Control	Postural stability, balance, physical function	Absolute values of mean total velocity significantly increased in AYT group (Eyes Open; t(8)=-3.66, p=0.01 and Eyes Closed; t(8)=-3.90, p=0.01). Significant baseline post AYT increase in somatosensory contribution to balance SI velocity (Eyes Open; t(8)=-2.42, p=0.04 and Eyes Closed; t(8)=-3.96, p=0.01). Significant increase in vestibular contribution to balance (t(8)=-2.47, p=0.04). Significant increase in one leg stand (z=-2.10, p=0.04), chair sit and reach (z=-2.22, p=0.01), and 30s chair stand (z=-1.98, p=0.05) following AYT program. No changes in control group.
Kingston, 2018 (USA)	Pre Post	No definition of blindness reported. Recruited from Blind Centre. Mean age = 80 yrs. % Males = 88% n = 24	Matter of Balance program (CBT and exercise training in 6 of 8 sessions; Tennstedt, 1998). 2 X 2 hours per week for 4 weeks.	None	Mobility and balance	Mean decrease of 2.15 sec on TUG, small increase in total POMA (1.5 points)
Kovács, 2012 (Hungary)	RCT	Visual acuity 20/30-20/400. Recruited from National Institution for Blind People. Aged ≥ 60 years and over.	Multimodal program - balance and strength exercises based on Otago Exercise Program, using increasing weights. Included 20-30min/day walking program. 30min X 2 week	Standard osteoporosis program alone (4Xwk).	Balance, everyday living activities, mobility, falls	Significant improvements in experimental group pre and post intervention (BBS 41.81 ± 7.52 v 45.09 ± 7.41 p=0.036, TUG 20.72±4.87 v 17.93±4.96 p<0.005). TUG time differed significantly between experimental and control (p=0.001). Number of falls = 22.

		Mean age = 68.7 ± 6.9 yrs (experimental) and 69.7 ± 6.5 yrs (control). % Males = 0% n = 41	multimodal exercise program + 2 X week standard osteoporosis program, for 6 months. n = 21 in intervention			Significantly shorter time to first fall in the control group (15 wks. V 19 weeks, p = 0.049).
Larsson, 2006 (Sweden)	Pre Post	Visual acuity of less than 0.05 in best eye or visual field less than 5 deg. Recruited from Low Vision Clinic. Of working age. Mean age = 52.3 ± 11.4 yrs % Males = 14% (of final participants) n = 8	Body awareness exercises and dance based training. 75min X 2 sessions week, for 8 weeks.	None	Balance, functional reach, functional balance, mobility, gait speed, Activity scale	Statistically significant improvements observed in; Functional reach = 6/7 TUG = 1/7 Max. Gait speed = 2/7 One leg stance (left) = 3/7 One leg stance (right) = 2/7 Max. Step length = 5/7
Miszko, 2004 (USA)	Pre Post	Recruited from local rehabilitation centre. Mean age = 52.6 ± 12.8 yrs. % Males = 70% n = 10	Tai Chi Classes. 2 X 1 hour, per week for 8 weeks, 15min per day outside of class, plus regular orientation and mobility training.	None	Muscular strength, work and power of knee; balance; functional reach and quality of life	Improvements seen in muscular strength (flexion 16.5%, extension16.9%), power (flexion 30%, extension 6.8%), and work (flexion 17.7%, extension 17.1%), small change in functional reach (0.75%) and BBS (2%), improvement in single stance time (6.3%). Improvement in frequency, independence and satisfaction with performing mobility tasks after tai chi.
Ponchillia, 1992 (USA)	Pre Post	Congenital total blindness. Recruited from University. Aged 24-37 yrs. % Males = 0% n = 3	Aerobics sessions led by trained instructor including high and low impact movements. 2 X 50 minutes per week, for 7 weeks.	None	Skinfolds, abdominal muscle strength and endurance, flexibility, heart rate, accuracy of performing tasks, step test.	Favorable changes in fitness based on step test, abdominal strength and endurance (24% mean increase on sit up test), body fat (mean 3.5% decrease) and accuracy of performance.
Salari, 2013 (Iran)	Pre Post	Blind athletes. Mean age = 22.4 ± 5.4 yrs. % Males = 0 % n = 30	Core stability training program. Approximately 3 X 1hr per week (every two days), for 8 weeks	None	Balance (measured by Flamingo Test and Y balance)	Significant increase in static and dynamic balance in anterior direction, internal posterior, external posterior and total balance.
Surakka, 2008 (Finland)	Pre Post	Partially sighted, blind or deaf-blind individuals. Mean age = 54 ± 9.9 yrs. % Males = 33% (of final participants) n = 27	Physical training including movements to improve balance, coordination, relax neck and shoulder muscles. 60 minutes 3 X per week for 5-6 weeks.	None	Physical condition, mental state and balance.	Self reported improvements in physical condition (22/24), mental state (21/24) and balance (11/24). Main motivators were better physical condition (21/24) and peer group (12/24)
Surakka, 2011 (Finland)	RCT	Partially sighted (best corrected visual acuity < 0.3) or blind (visual acuity < 0.1, or visual field < 10 deg with glare and hemeralopia). Recruited from Rehabilitation Services at a tertiary hospital. Mean age = 55 ± 9.0 yrs (experimental) and 57 ± 7.2yrs (control). % Males = 45% n = 29	Physical training designed for VI and deaf-blind persons to improve balance, posture, coordination, tense neck and shoulder muscles, and loss of spinal rotation and reciprocal arm swing. 60 minutes 3 X per week for 5-6 weeks. N=15 in intervention	No intervention	Flexibility	Significant improvement in flexibility of trunk in the experimental v control group (p=0.0068).

Waterman, 2016 (UK)	RCT	Binocular visual acuity > 0.6, Snellen equivalent = 6/24 and/or moderate visual field loss (>20% of the test locations in a binocular Esterman test). Recruited from the community. Mean age = 81.4 ± 8.6 yrs. % Males = 35% n = 49	Home Safety Arm (occupational therapist discussion with participants and action plan to alter environment to reduce risk of falls). Home exercise program arm (based on Otago Exercise Program involving strength and balance exercises in addition to walking). 30min X 3 times per week plus walking X 2 times per week, for 6 months. n = 17 in intervention	Usual care plus social visits	Number of falls, fear of falls, adherence rates, quality of life	No statistically significant differences.

Abbreviations: AUS = Australia, AYT = Ashtanga-Based Yoga, BBS = Berg Balance Score, CST = Chair Stand Test, HK = Hong Kong, NZ = New Zealand, POMA = Performance Oriented Mobility Assessment, RCT = Randomized Controlled Trial, SOT = Sensory organization test, 6MWT = Six minute walk test, TUG = Timed Up and Go, UK = United Kingdom, USA = United States of America, VI = visual impairment.

PRISMA 2009 Checklist

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

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-15
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	17-18
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Fig 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Fig 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	18
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	19-22
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	21-22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	22
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	23

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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BMJ Open

Physical Activity Interventions for Adults who are Visually Impaired: A Systematic Review and Meta-Analysis

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-034036.R1
Article Type:	Original research
Date Submitted by the Author:	28-Dec-2019
Complete List of Authors:	Sweeting, Joanna; The University of Sydney, Charles Perkins Centre; The University of Sydney School of Public Health, Prevention Research Collaboration Merom, Dafna; Western Sydney University School of Science and Health, Physical Activity and Health Astuti, Putu; The University of Sydney School of Public Health, Prevention Research Collaboration; Universitas Udayana, Department of Public Health and Faculty of Medicine Antoun, Michael; The University of Sydney, Sydney Dental School Edwards, Kate; The University of Sydney, Charles Perkins Centre; The University of Sydney, Faculty of Health Sciences Ding, Ding; The University of Sydney, Charles Perkins Centre; The University of Sydney, Prevention Research Collaboration
Primary Subject Heading:	Public health
Secondary Subject Heading:	Sports and exercise medicine
Keywords:	PUBLIC HEALTH, SPORTS MEDICINE, PREVENTIVE MEDICINE

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Physical Activity Interventions for Adults who are Visually Impaired: A Systematic Review and Meta-Analysis

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Word Count: 3,765

ABSTRACT

Objectives: Compared with sighted individuals, people with visual impairment have a higher prevalence of chronic conditions and lower levels of physical activity. This review aims to systematically review physical activity interventions for those with a visual impairment and to assess their effectiveness.

Design: A systematic review of articles reporting physical activity interventions in visually impaired individuals was conducted. Medline, EMBASE, The Cochrane Library, Cumulative Index to Nursing and Allied Health Literature (CINAHL), SPORTDiscus, and the Physiotherapy Evidence Database (PEDro) were searched in August 2018. Meta-analyses were conducted on randomised controlled trials with the same outcome measure.

Setting: Most interventions were conducted in a group setting, with some including an at-home, self-directed component.

Participants: Following identification of a recent systematic review of physical activity interventions in children, our review focused on adults aged 18 years and older with a visual impairment.

Primary and secondary outcome measures: Outcomes included measures of balance, mobility, mental well-being (e.g. quality of life), number of falls, muscle strength, flexibility, and gait.

Results: Eighteen papers from 17 studies met inclusion criteria. Physical activity components include falls prevention and/or balance-based activities, walking, Tai Chi, Alexander Technique, Yoga, dance, aerobics and core stability training. Significant results in favour of the intervention were reported most commonly in measures of functional capacity (9/17 studies) and in falls/balance related outcomes (7/13 studies). The studies

identified were generally small and diverse in study design, and risk of bias was high across several categories for most studies. Meta-analyses indicated non-significant effects of the included interventions on the Timed Up and Go, Chair Sit Test and Berg Balance Scale.

Conclusions: Physical activity interventions in individuals with visual impairment incorporating activities such as Tai Chi, Yoga and dance can have positive results, particularly in physical measures such as mobility and balance. However, when performing a meta-analysis of randomised control trials, the evidence for effectiveness is less clear. More studies with larger sample sizes, stronger designs, and longer follow-up periods are needed.

PROSPERO Registration: PROSPERO CRD42018103638; record available from https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=103638

ARTICLE SUMMARY

Strengths and limitations of this study

- This systematic review was registered a priori and conducted in line with PRISMA and AMSTAR 2 guidelines.
- Six databases were used and a back-reference search of all included studies was conducted, with no limit on language or year of publication imposed.
- Risk of bias analysis was conducted independently by two reviewers using the validated Cochrane Collaboration tool.
- A lack in common outcome measures allowed inclusion of only four studies in the meta-analysis.

INTRODUCTION

Physical activity is well established as a prophylactic for many non-communicable diseases including cardiovascular disease, certain cancers, hypertension and type 2 diabetes.(1, 2) In addition to physical health, regular physical activity is also known to benefit psychological wellbeing including a reduction in the risk of depression and anxiety, lowering of stress levels and improving mood.(3, 4) The Centers for Disease Control and Prevention (CDC) recommends at least 150 minutes per week of moderate-intensity aerobic physical activity (or equivalent vigorous activity) for adults (aged 18-64).(5) However, with the global prevalence of insufficient physical activity at nearly 30% in 2016, it is imperative that regular physical activity continues to be promoted and encouraged worldwide.(6) This is important not only in healthy populations, but also in those with diseases and conditions, such as cardiovascular disease and disabilities such as visual impairment. As highlighted by the CDC in the current physical activity guidelines, there is strong evidence that regular physical activity conveys important health benefits for individuals with a disability.(5) However, adults with disabilities are three times more likely to have chronic conditions such as heart disease, diabetes and cancer, and nearly 50% of adults with a disability undertake no leisure time physical activity.(6) More research among those with specific disabilities is needed to address these gaps and improve health outcomes for those with a disability.(7)

In the United States, the five most common functional disabilities are in mobility, cognition, independent living, hearing and vision.(8) In 2015, an estimated 36 million people worldwide were blind (0.49% of the total population, visual acuity worse than 3/60), 217 million (2.95%) had moderate or severe vision impairment (visual acuity worse than 6/18 and 6/60, respectively) and another 189 million (2.57%) had mild vision impairment (visual acuity worse than 6/12). The most common causes of vision impairment include

uncorrected refractive errors, cataracts, age-related macular degeneration, glaucoma, and diabetic retinopathy.(9)

Visual impairment has been shown to detrimentally impact quality of life (10, 11) and to be associated with depression.(12) Also concerning is the fact that studies have shown a higher mortality rate for visually impaired individuals compared with their sighted counterparts, although the underlying reasons are uncertain.(13, 14) Even at the mild end of the impairment spectrum, loss of vision can affect health and wellbeing, for example, through restriction of driving, potentially impacting an individual's sense of autonomy and freedom.(15) Vision impairment has also been shown to be associated with less time spent in moderate-vigorous physical activity in the range of 26-48% compared to sighted individuals.(16-18) One potential reason for this discrepancy is the fear of falling associated with loss of vision and consequent poor balance.(16, 17) For those able to navigate their local environment with the assistance of a guide dog or cane, physical barriers such as uneven, slippery or blocked footpaths can make it difficult to perform adequate physical activity.(19) With the adverse effects that visual impairment can have on wellbeing, and extra challenges those with visual impairments face, it is of upmost importance that physical activity is encouraged in this population, given its beneficial impact on health and wellbeing.

To date, few interventions have included participants with vision impairment. In fact, it is more often the case that visual impairment or blindness are exclusion factors from physical activity interventions. With increasing recognition of the health disparities experienced by people living with disabilities and the lack of research by contrast,(20) it is important to ensure that the principle of inclusiveness is applied so that interventions are designed for those with disabilities. This review aims to systematically review physical activity interventions for those with vision impairment and to assess the effectiveness of the

interventions in improving health-related (physical and mental) outcomes and issues encountered.

METHODS

Eligible studies

This systematic review included peer-reviewed articles reporting on physical activity interventions in visually impaired individuals. The research questions, search strategy and inclusion/exclusion criteria were determined prior to commencing the search and the review was registered on the International Prospective Register of Systematic Reviews (PROSPERO CRD42018103638; record available from https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=103638). Although the initial research plan was to review studies across all age categories, the population of interest was restricted to adults (aged 18 years and over) following the initial search as a recent systematic review among children and adolescents was identified.(21) We included experimental studies focusing on a physical activity intervention or those examining interventions with a clear physical activity component. Controls included individuals not exposed to the intervention or the baseline measurements of participants prior to commencement of the intervention (pre-post study design). Both randomised control trials and non-randomised studies of interventions, including pre-post studies without a comparison group, were included to provide a more complete picture of all the studies in the literature, given the small number expected. Observational studies, reviews, case reports, abstracts, commentaries or other opinion pieces were excluded. No limit on publication date or language of publication was set to ensure broad coverage of the literature. Outcome measures included a range of physical measurements, such as body fat percentage, blood pressure, body mass, waist circumference; physical activity/fitness measures such as flexibility, daily step count, balance and muscle strength and endurance; and wellbeing measures including social and emotional wellbeing and depression.

Sources and Search Strategy

We searched Medline (1946 – August 2018), EMBASE (1947 – August 2018), The Cochrane Library (1993 – August 2018), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (1982 – August 2018), SPORTDiscus (1892 – August 2018), and the Physiotherapy Evidence Database (PEDro) (1929 – August 2018). Back references of all papers included in the review were also searched to identify additional articles. Search terms included those related to blindness and visual impairment (e.g. vision disorders, visually impaired person, glaucoma) and physical activity (e.g. exercise, sports, muscle strength, gait, dancing, and rehabilitation). A targeted search of the Journal of Visual Impairment and Blindness was conducted due to indexing issues discovered during the back-reference search. One article was discovered through this additional search. The final search strategy for Medline is outlined in Supplementary Material 1. This search strategy was adapted for use with the other bibliographic databases in combination with database-specific filters. An initial screen of all abstracts was conducted to identify potentially relevant studies (MA and JS). These studies were then simultaneously and independently reviewed by two reviewers (DD and PASA) to determine eligibility for inclusion in this review, with a third reviewer (DM) enlisted in the case of disagreement.

Data collection

Data were extracted from the eligible papers by JS and summarised into an Excel spreadsheet with the following headings: Author, Year of Publication, Population (including age) and Setting, Visual Conditions, Exclusion Criteria, Study Design, Control Group, Theory (behind the intervention), Type of Physical Activity Intervention, Dose of Intervention (times per week, duration), Delivery (who delivered the intervention), Outcomes, Process Evaluation (e.g. participation, adherence, drop out, feedback),

Results, Other Notes and Funding Sources. We further condensed the extracted data under the headings seen in Tables 1 and 2. Data extraction was checked by KE with agreement achieved on all studies through discussion. Data for one paper written in Farsi was extracted by a collaborator fluent in Farsi.

Analysis

The main characteristics and findings of each study were summarised and tabulated to provide an overview of the literature to date in this area. Where measures were common across RCT studies, a meta-analysis was conducted, using R Foundation for Statistical Computing, version 3.6.0 to estimate the standardised mean difference (SMD) and 95% confidence interval to assess the effectiveness of the interventions. The I^2 was calculated as a measure of heterogeneity between studies. This review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)(22) and A Measurement Tool to Assess Systematic Reviews (AMSTAR2) guidelines (23) (Supplementary 2 and 3). Risk of bias assessment was performed by JS and PASA, using the Cochrane Collaboration's tool for assessing risk of bias. This tool was used to rate each randomised controlled trial (RCT) with a low, high or uncertain risk of bias across six criteria including randomisation, allocation concealment, performance bias, ascertainment bias, incomplete outcome data and selective reporting.(24) For non-randomised studies we considered the risk of bias due to incomplete data and selective reporting.

Patient and Public Involvement

Neither patients nor the public were involved in the design, conduct, reporting or dissemination of this research.

RESULTS

Study selection

A total of 10,112 records were returned, with 6,517 unique record titles and abstracts screened for possible inclusion. Of these, 56 full texts were obtained and reviewed, with 18 papers (from 17 studies) meeting the inclusion criteria (Figure 1). Primary reasons for exclusion were: the studies were conducted in children under the age of 18 (n=19), were not reporting results of a trial of an intervention (e.g. protocol papers) (n=14) and did not include physical activity as a key component of the intervention (n=5). The studies were predominately funded by Government and/or Research Grants (n=9), with funding sources not specified by six studies. One intervention which examined the impact of the Alexander technique (25, 26) was funded by private sources including The Australian Society of Teachers of the Alexander Technique and the FM Alexander Trust (UK), in addition to government and research funding. One intervention was not sponsored.

Study characteristics

The characteristics of the studies are shown in Supplementary Material 4 and summarised in Table 1. Most of the papers (n=14, 78%) were published in the ten years preceding the date of the search (2008-2018). Nine employed a randomised control trial study design, with the remaining eight studies using a pre-post format. Seven interventions were conducted in the United States with the remaining studies conducted in Europe (n= 5), Asia (n=3), and Oceania (n= 2). Except for one study that was published in Farsi, all studies were published in English.

Table 1. Summary of included interventions

	Falls Prevention and Balance Interventions							Other Intervention Types									Mixed
	Campbell (2005)	**Cheung (2008)**	**Kingston (2018)**	**Kovács (2012)**	**Surakka (2008)**	**Surakka (2011)**	**Waterman (2016)**	**Ackley-Holbrook (2016)**	**Chen (2012)**	**Gleeson (2015, 2017)**	**Jeter (2012)**	**Jeter (2015)**	**Larsson (2006)**	**Miszko (2004)**	**Ponchillia (1992)**	**Salari (2013)**	**Hackney (2015)**
Study Design	RCT	RCT	PP	RCT	PP	RCT	RCT	PP	RCT	RCT	PP	RCT	PP	PP	PP	PP	RCT
Sample size	391	50	24	41	27	29	49	21	40	120	10	21	8	10	3	30	32
Mean age (yrs)	84	83	80	69	54	56	81	48	86	75	46	55	52	53	31	22	79
Basis of PA Intervention	Otago	Balance + Strength	Matter Of Balance	Otago	Balance	Balance	Otago	Walking	Tai Chi	Alexander Technique	Yoga	Yoga	Dance	Tai Chi	Aerobics	Core stability	Exp.= Dance Ctrl= FallProof
Delivery mode[a]	Self-directed	Group	Group	Group	Group or mixed	Group	Self-directed	Self-directed	Group	Group	Mixed	Mixed	Group	Mixed	Group	-	Group
Duration	1yr	12wks	4wks	6mths	5-6wks	5-6wks	6mths	8wks	16wks	12wks	8wks	8wks	8wks	8wks	7wks	8wks	10-12wks
Compliance	18%	100%	-	95%	Mean # sessions = 13.5	-	Equivocal	94%	-	100%	-	82% sessions 90% home practice	-	-	-	-	25/32 completed all sessions
Retention	92%	100%	100%	100%	89%	100%	88%	81%	62%	93%	70%	81%	88%	80%	100%	-	78%
Adverse Outcomes	N = 1 moderate injury	None	-	N = 22 falls	-	-	None	N = 2 falls	-	N = 2 deaths, N=1 hospitalisation	-	None	-	None	-	-	-
Results[b]																	
Falls and Balance	Mixed	+	NT	0	DA	NT	0	NT	+	+ (postural sway)	DA	+	~ +	DA	NT	+	+
Functional Capacity	NT	+	DA	+	NT	+	NT	+	+	0	NT	+	~ +	DA	~ +	NT	+
Psych. well-being	NT	NT	NT	NT	DA	NT	0	NT	NT	0	DA	NT	NT	DA	NT	NT	0

[a] Mixed = self-directed sessions in combination with regular group classes or face to face session; Group = group class-based only.

[b] + = statistically significant result in favor of intervention, 0 = no statistically significant change, ~+ = analysis at individual level showing significant change, DA = descriptive analysis only, NT = not tested.

'-' = Not reported

Abbreviations: PP - pre-post; RCT – randomised controlled trial

Participants

There was a total of 906 participants across the 17 interventions, with a mean of 53 and a median of 29 per study. The number of participants per study ranged from three to 391 with 14 studies with 50 or fewer participants. The mean age across all studies was 62 years, with only two (27, 28) examining populations aged younger than 35 years. Approximately two-thirds (70%) of participants were female, with three studies only including women.(27, 29, 30) Participants were recruited through a combination of local advocacy groups, community center listings, and by word-of-mouth in four studies. In eight studies participants were recruited from medical institutions such as hospitals, clinics, private practices and rehabilitation services. In two studies participants were recruited from residential care homes and one recruited participants from a university (recruitment method unknown in two studies).

Visual impairment was defined in several ways with varying levels of detail. Most studies provided cut-points of visual acuity (e.g. 6/24 or worse), while some linked these cut points to those designated by the World Health Organization International Classification of Diseases Codes.(31, 32) Visual conditions identified included age-related conditions such as macular degeneration and cataracts, diabetic retinopathy, glaucoma, corneal scars, and congenital blindness.

Intervention types

Seven studies employed specific falls prevention and/or balance-based physical activity interventions. Of these, three used the Otago exercise program,(30, 33, 34) three used general physical activity training programs aiming to improve balance,(29, 35, 36) and one used the Matter of Balance program.(37, 38) The remaining interventions were based on

other forms of physical activity including walking (n=1),(31) Tai Chi (n=2),(39, 40) Alexander Technique (n=1),(25, 26) Yoga (n=2),(41, 42) dance (n=1),(43) aerobics (n=1) (27) and core stability training (n=1).(28) One study utilised a falls prevention program (FallProof) as a control, comparing to a dance-based intervention program.(32) The interventions were predominately delivered in a group based, face-to-face format with only three being chiefly self-directed with periodic contact from investigators.(31, 33, 34) The interventions ran for an average of 13 weeks (range of four weeks – one year) with three-quarters (n = 13/17, 76%) having a duration of 4 -12 weeks.

Objectives

In general, each intervention aimed to assess the impact of a physical activity program on falls risk or balance, physical health, and/or mental health. Four interventions aimed to compare the physical activity intervention to another program such as a home safety program,(33, 34) fall prevention program,(32) or osteoporosis program.(30) Eight interventions aimed to cater specifically for “older” or “elderly” individuals. One study focused on female athletes.(28) Two studies examined the cost-effectiveness of the intervention.(33, 34)

Outcome measures

As summarised in Table 2, the most common outcomes were measures of balance, reported in 65% of the interventions (Berg Balance Scale [BBS], n = 4; other measures e.g. sensory organisation test [SOT] and one legged stance [OLS], n = 9). Six studies (35%) examined the impact of the intervention of an aspect of mental well-being such as anxiety, depression, or quality of life. Measures of mobility were used in five studies (29%),

most commonly the timed up and go (TUG) test (n=5). Other outcome measures included number of falls (n=4), muscle strength (n=3), flexibility (n=3), gait (n=3), anthropometric measures (n=3), the chair stand test (n=2) and sleep (n=1).

Table 2 Summary of outcome measures

	OUTCOME	Ackley-Holbrook (2016)	Campbell (2005)	Chen (2012)	Cheung (2008)	Gleeson (2015, 2017)	Hackney (2015)	Jeter (2012)	Jeter (2015)	Kingston (2018)	Kovács (2012)	Larsson (2006)	Miszko (2004)	Ponchillia (1992)	Salari (2013)	Surakka (2008)	Surakka (2011)	Waterman (2016)
Balance	Number of Falls		X			X					X							X
	Berg Balance Scale				X		X				X		X					
	Other Balance[a]			X		X	X	X	X			X	X		X	X		
Functional Capacity	Timed Up and Go				X		X			X	X	X						
	Other Mobility[b]									X	X							
	Chair Stand Test				X	X												
	Other Fitness[c]	X				X	X					X		X				
	Muscle strength			X									X	X				
	Flexibility								X					X			X	
Other	Psychological well-being[d]					X	X	X					X			X		X

[a] Including measures of postural sway and stability (Sensory Organisation Test, One Legged Stance, Mean Stride Length, Functional Reach).

[b] Including Performance-oriented mobility assessment and Activity Index

[c] Including six-minute walk test, step count, gait measures.

[d] Including measures of quality of life, anxiety, depression, emotional wellbeing.

Synthesis of Results

Falls or balance related outcomes were measured in 13 studies, with statistically significant results in favor of the intervention observed in seven studies (54%). Although more falls were recorded in the intervention group in the Campbell et al. (2005) study, further analysis showed fewer falls with increasing adherence to the exercise program (p=0.001). Measures of functional capacity were used in 12 studies, with statistically significant results in favor of the intervention observed in nine studies (75%). Psychological well-being was measured in only six studies and no significant results were observed in these outcomes. No paper reported negative results that would suggest the intervention was detrimental to any aspect of health measured. Drop out reasons across all studies included medical problems (n=10), lack of transport or travel time (n=7), dissatisfaction with program (n=1), time (n=2), other (n=3).

Effectiveness of Interventions on PA outcomes

A meta-analysis was conducted where outcome measures were common across RCT interventions, namely for the Timed Up and Go (TUG), Chair Sit Test (CST) and Berg Balance Scale (BBS). Only four studies were able to be included in the meta-analysis and the results are shown in Figure 2. In all instances, the combined results crossed the line of null effect (mean difference = 0) indicating non-significant effects of the interventions on each of the outcome measures. In addition, the wide 95% confidence intervals indicate imprecision across the studies, potentially due to small sample sizes. Heterogeneity was low for the TUG and CST (I^2 = 0% and 22%, respectively) suggesting consistent null findings, however, it was high for the BBS (I^2 = 53%).

Study Quality – Risk of Bias Assessment

The results of the Risk of Bias assessment can be found in Table 3. In general, the randomised controlled trials showed a low risk of bias in randomisation (n=6/9 'low') and allocation concealment (n=6/9 'low'). Risk of attrition bias due to incomplete data was also low in the majority of all studies (n=11/17). Of note, all but one study was categorised as 'unclear' or 'high' risk of reporting bias due to selective outcome reporting. In all pre-post studies it was not possible to determine if all outcomes were reported due to the lack of study protocol or registrations. Of the nine randomised controlled trials, study protocols were unavailable for five, two were missing a priori secondary outcomes, one followed the study protocol, and one deviated from the study protocol.

Table 3. Risk of bias assessment for randomised control trials (RCTs) and pre-post studies

	Risk of bias (High, low, unclear)					
Source	**Randomisation sequence allocation**	**Concealment**	**Performance bias**	**Ascertainment bias**	**Incomplete outcome data**	**Selective reporting**
RCTs						
Campbell et al (2005)	LOW	LOW	UNCLEAR	UNCLEAR	LOW	UNCLEAR
Chen et al (2012)	UNCLEAR	UNCLEAR	LOW	LOW	LOW	UNCLEAR
Cheung et al., (2008)	LOW	LOW	LOW	LOW	LOW	UNCLEAR
Gleeson et al. (2015, 2017)	LOW	LOW	UNCLEAR	LOW	LOW	UNCLEAR
Hackney et al. (2015)	HIGH	HIGH	HIGH	UNCLEAR	LOW	UNCLEAR
Jeter et al (2015)	LOW	LOW	HIGH	LOW	LOW	HIGH
Kovacs et al (2012)	LOW	LOW	UNCLEAR	LOW	LOW	UNCLEAR
Surakka et al (2011)	UNCLEAR	UNCLEAR	HIGH	HIGH	UNCLEAR	UNCLEAR
Waterman et al (2016)	LOW	LOW	HIGH	LOW	LOW	LOW
Pre-post with no comparison group						
Ackley-Holbrook et al (2016)	---	---	---	---	LOW	UNCLEAR
Jeter (2012)	---	---	---	---	HIGH	UNCLEAR
Kingston (2018)	---	---	---	---	UNCLEAR	UNCLEAR
Larsson (2006)	---	---	---	---	LOW	UNCLEAR
Miszko (2004)	---	---	---	---	UNCLEAR	UNCLEAR
Ponchillia (1992)	---	---	---	---	LOW	UNCLEAR
Salari (2013)	---	---	---	---	UNCLEAR	UNCLEAR
Surakka (2008)	---	---	---	---	UNCLEAR	UNCLEAR

--- Not applicable

DISCUSSION

This systematic review sought to summarise the effects of physical activity interventions in adults who are visually impaired. Based on the studies identified, there is evidence that physical activity interventions are beneficial to adults with visual impairment, with positive health benefits observed particularly in outcomes related to functional capacity. However, when focusing on RCTs, where the risk of bias is lower, and examining combined results in a meta-analysis, the evidence for intervention effectiveness is less clear.

This review identified seventeen intervention studies, which represents a considerably small evidence base, particularly in contrast to the size of the problems related to physical inactivity, health conditions and challenges faced by many people with visual impairment. Several characteristics of existing studies have also limited the internal and external validity. First, most studies included very small sample sizes with four presenting descriptive analysis only (did not report inferential statistics) and two reporting results at an individual, rather than group level. Second, there was a substantial imbalance in both gender (70% female participants) and age with all but two studies focused on individuals aged older than 45 years. However, overrepresentation of female participants is common in health interventions and people aged 50 years and older represent 65% of all visually impaired persons worldwide (and 82% of blind persons).(44) Third, more than three-quarters of the studies ran for 12 weeks or less, limiting the ability to assess maintenance of changes observed and effects on outcomes that may take time to change. For example, of the six studies assessing psychological well-being and mental health outcomes, none reported statistically significant improvements. However, promising results were observed in measures of functional capacity, such as mobility and fitness, and balance, even in a relatively short time period of 5-6 weeks.(36) To address these issues future interventions should, where possible, employ an

RCT study design with a priori calculation of participants needed to ensure the study is powered for more robust statistical analysis. If feasible, a longer duration would also be of benefit, particularly in establishing the impact of the interventions on mental health outcomes. Also, a targeted approach to include males and those aged 18-45 years may be appropriate to address the underrepresentation of these demographics in the current literature.

A wide range of physical activities were used by the intervention studies, most of which focused on low-intensity physical activities, such as yoga and Tai Chi, with a strong emphasis on improving balance and stability. Only one study incorporated higher intensity activity in the form of aerobics with “many high-impact (bouncing and jumping) … movements”.(27) However, this study was also the smallest with only three participants, so it is hard to determine its effects. Although the benefits of yoga, Tai Chi and other low-intensity activities have been documented,(45-47) moderate and vigorous physical activity have further health benefits and are generally the primary focus of global physical activity guidelines.(5) The current CDC guidelines recommend a minimum of 150 minutes per week of moderate activity per week (or 75 minutes of vigorous activity) (5) with the evidence on light intensity physical activity not yet conclusive for informing guidelines.(1) Although these guidelines highlight a dose-response relationship whereby more health benefits are gained with an increase in moderate intensity physical activity undertaken, even small increases in physiological capacity / physical activity provide significant reduction in mortality risk.(48, 49) This suggests that future physical activity interventions among those with visual impairment should consider incorporating some physical activity at a moderate intensity or higher, even if only in small doses in older individuals. Although on the surface visual impairment may appear to be a barrier to undertaking moderate or vigorous physical activity, the existence of numerous sports for visually impaired athletes at Paralympic level would suggest otherwise.(50) Even

though few individuals reach this height of athletic ability, it is evident that visually impaired individuals can perform higher intensity activities, evidenced by the feasibility of physical activity trials with walking and aerobics as the intervention.(27, 31) Therefore, development of interventions for moderate and / or vigorous physical activity could form a focus in future work. Moreover, given the increased risk of poorer physical and mental health for those who are visually impaired,(13, 51) it is important to ensure they are given opportunities to undertake physical activity at higher intensities in order to garner the further health benefits.

In terms of delivery mode, studies were predominately group-based, with nine of sixteen (delivery mode unknown in one study) purely delivered in a face-to-face manner, and a further four involving group classes with additional self-directed practice at home. The remaining three studies were of a more self-directed nature with varying levels of investigator involvement including five home visits throughout the year-long study,(33) five home visits (from occupational therapist or peer mentor) and two phone calls over the six month duration,(34) and a single orientation session followed by self-directed activity.(31) Further intervention studies could compare the effectiveness of group-based and self-directed trials to determine the possibility of reducing investigator burden in delivery by increasing self-directed options where possible. This would have the added benefit of incorporating capacity building into the intervention and enabling participants to continue in their new habits post-intervention. Alternatively, the use of already existing programs such as regular community dance classes could be examined as a means of increasing the likelihood of maintaining changes to physical activity behaviors following the intervention. To our knowledge, none of the group-based interventions identified allowed participants to continue in the physical activity following the study as they were all conducted for research purposes only. However,

given the habitual nature physical activity, it is possible highly motivated individuals may have continued to practice in their own homes following instruction during the intervention.

Strengths and limitations

The strengths of this systematic review include incorporating both qualitative and quantitative evidence synthesis, following AMSTAR2 and PRISMA guidelines, and not restricting literature search by publication language and dates. Limitations relate to the studies identified, rather than the review process itself. The studies identified were generally small with diverse study designs and outcomes measured. This made it challenging to determine the effectiveness of the interventions and to identify the aspects that should be retained in subsequent studies. Most studies lasted for a short period of time without intended examination for longer-term maintenance. Finally, the quality assessment showed a high risk of bias across the papers in several categories.

CONCLUSION

Given the higher risk of developing non-communicable diseases for those with visual impairment, it is imperative that sufficient physical activity is undertaken by these individuals to ensure that they benefit from the positive health outcomes. This systematic review illustrates that physical activity interventions in individuals with visual impairment can have beneficial results, particularly in physical measures such as mobility and balance. However, when performing a meta-analysis of RCTs, the evidence for effectiveness is less clear. More high quality research needs to be conducted in larger groups, with a focus on specific age

groups and over longer periods of time to enable the optimisation of further interventions. Additionally, future studies need to incorporate interventions that equip the participants with skills and confidence to sustain their new physical activity behaviors post-intervention. Finally, more research is required into the feasibility of interventions that address the need for moderate and vigorous physical activity, which unlock even more health benefits compared to the low intensity activities reported in this systematic review.

AUTHOR CONTRIBUTIONS

JS, DM, MA, KME, and DD were involved in study design. JS and MA performed the systematic search, JS, DM, PASA, KME and DD made significant contributions to the analysis and/or interpretation of the data. JS, DM, PASA, MA, KME and DD all contributed to drafting and revising the work.

ACKNOWLEDGEMENTS

The authors wish to thank Dr Javad Koohsari, from Waseda University, Japan, for helping with translation and data extraction from a study published in Farsi.

FUNDING

The work was supported by a Sydney Research Accelerator (SOAR) prize awarded to Ding. Ding is funded by a National Heart Foundation Future Leader Fellowship.

COMPETING INTERESTS

None declared.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article or uploaded as supplementary information.

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FIGURE LEGENDS

Figure 1 PRISMA FlowChart

Figure 2 Forest Plots from Meta Analyses. A) Timed Up and Go. B) Chair Stand Test. C) Berg Balance Scale. Abbreviations; CI = confidence interval, MD = mean difference, RE = Random Effects

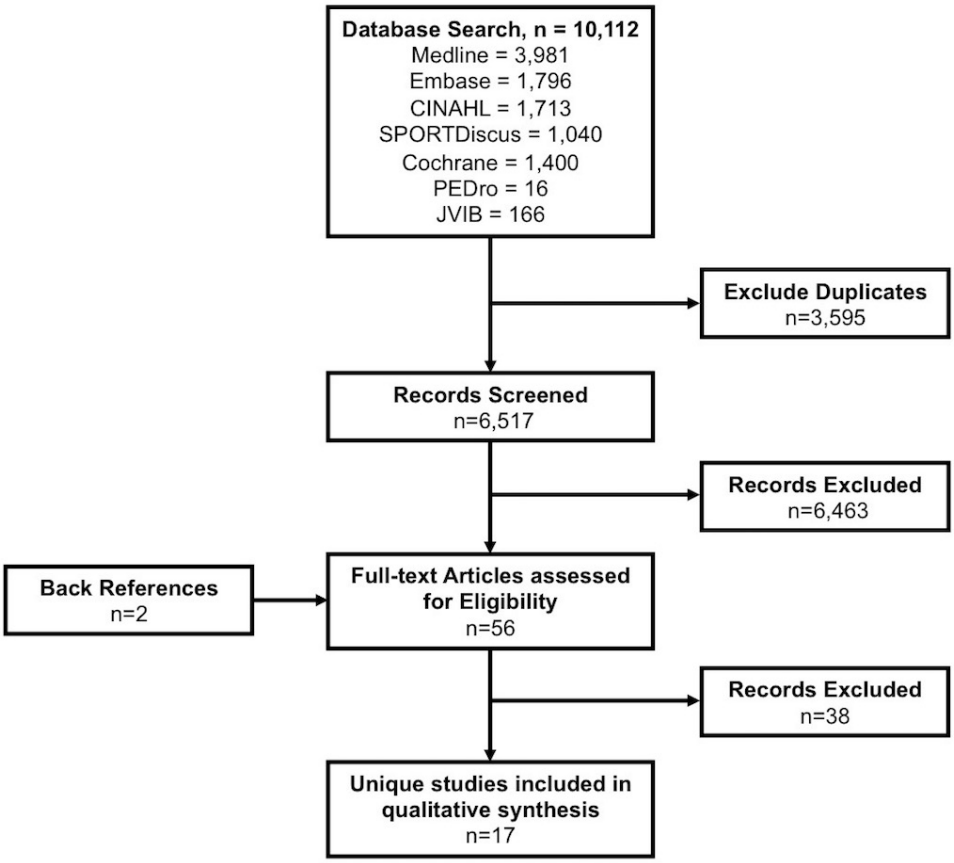

Figure 1. PRISMA FlowChart of study selection

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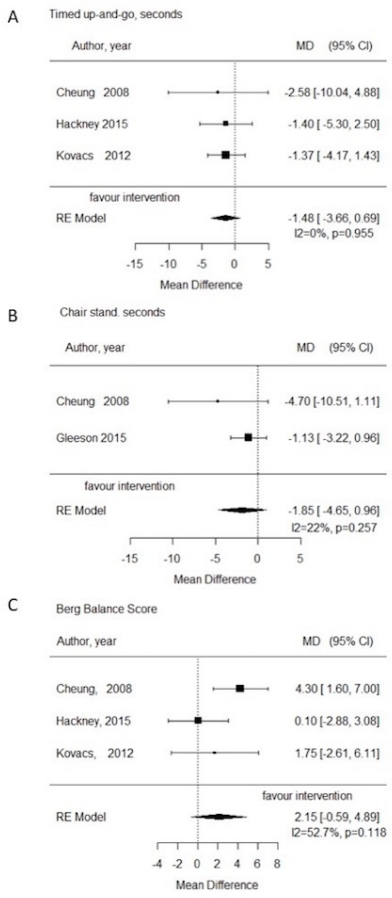

A. Timed Up and Go. B . Chair Stand Test. C. Berg Balance Scale

Figure 2. Forest plots of meta-analyses: A. Timed Up and Go. B . Chair Stand Test. C. Berg Balance Scale

90x90mm (300 x 300 DPI)

Supplementary Material 1. Search strategy for Medline

Vision Related Terms	Physical Activity Terms
MeSH TERMS	
Vision Disorders	Exercise
Visually Impaired Persons	Exercise therapy
Glaucoma	Sports
Retinal Diseases	Tai ji
Cataract	Yoga
	Dancing
	Postural Balance
	Posture
	Muscle Strength
	Gait
	Mobility Limitation
	Exercise movement techniques
	Walking
	Rehabilitation
	Dance therapy
	Occupational therapy
	Recreation therapy
KEYWORD SEARCH TERMS	
Vision*or visual*or eye*or sight adj3 (impair* or loss or disorder* or disease* or disabl*))	Exercise
Blindness	Physical* adj3 activ*
	Danc*

Vision related terms combined with “OR”.

Physical activity terms combined with “OR”.

Vision related and physical activity terms combined with “AND”.

Supplementary 2 - PRISMA Checklist

PRISMA 2009 Checklist

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

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-15
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	17-18
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Fig 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Fig 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	18
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	19-22
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	21-22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	22
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	23

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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

Supplementary 3 - AMSTAR 2 Checklist

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

1. Did the research questions and inclusion criteria for the review include the components of PICO?

For Yes:
- ☑ Population
- ☑ Intervention
- ☑ Comparator group
- ☑ Outcome

Optional (recommended)
- ☐ Timeframe for follow-up

- ☑ Yes
- ☐ No

2. Did the report of the review contain an explicit statement that the review methods were established prior to the conduct of the review and did the report justify any significant deviations from the protocol?

For Partial Yes:
The authors state that they had a written protocol or guide that included ALL the following:
- ☑ review question(s)
- ☑ a search strategy
- ☑ inclusion/exclusion criteria
- ☑ a risk of bias assessment

For Yes:
As for partial yes, plus the protocol should be registered and should also have specified:
- ☐ a meta-analysis/synthesis plan, if appropriate, *and*
- ☐ a plan for investigating causes of heterogeneity
- ☐ justification for any deviations from the protocol

- ☐ Yes
- ☑ Partial Yes
- ☐ No

3. Did the review authors explain their selection of the study designs for inclusion in the review?

For Yes, the review should satisfy ONE of the following:
- ☐ *Explanation for* including only RCTs
- ☐ OR *Explanation for* including only NRSI
- ☑ OR *Explanation for* including both RCTs and NRSI

- ☑ Yes
- ☐ No

4. Did the review authors use a comprehensive literature search strategy?

For Partial Yes (all the following):
- ☑ searched at least 2 databases (relevant to research question)
- ☑ provided key word and/or search strategy
- ☑ justified publication restrictions (e.g. language)

For Yes, should also have (all the following):
- ☑ searched the reference lists / bibliographies of included studies
- ☑ searched trial/study registries
- ☑ included/consulted content experts in the field
- ☑ where relevant, searched for grey literature
- ☑ conducted search within 24 months of completion of the review

- ☑ Yes
- ☐ Partial Yes
- ☐ No

5. Did the review authors perform study selection in duplicate?

For Yes, either ONE of the following:
- ☑ at least two reviewers independently agreed on selection of eligible studies and achieved consensus on which studies to include
- ☐ OR two reviewers selected a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder selected by one reviewer.

- ☑ Yes
- ☐ No

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

6. Did the review authors perform data extraction in duplicate?

For Yes, either ONE of the following:

- ☑ at least two reviewers achieved consensus on which data to extract from included studies
- ☐ OR two reviewers extracted data from a sample of eligible studies and achieved good agreement (at least 80 percent), with the remainder extracted by one reviewer.

☑ Yes
☐ No

7. Did the review authors provide a list of excluded studies and justify the exclusions?

For Partial Yes:

- ☐ provided a list of all potentially relevant studies that were read in full-text form but excluded from the review

For Yes, must also have:

- ☐ Justified the exclusion from the review of each potentially relevant study

☐ Yes
☐ Partial Yes
☑ No

8. Did the review authors describe the included studies in adequate detail?

For Partial Yes (ALL the following):

- ☑ described populations
- ☑ described interventions
- ☑ described comparators
- ☑ described outcomes
- ☑ described research designs

For Yes, should also have ALL the following:

- ☑ described population in detail
- ☑ described intervention in detail (including doses where relevant)
- ☑ described comparator in detail (including doses where relevant)
- ☑ described study's setting
- ☑ timeframe for follow-up

☑ Yes
☐ Partial Yes
☐ No

9. Did the review authors use a satisfactory technique for assessing the risk of bias (RoB) in individual studies that were included in the review?

RCTs

For Partial Yes, must have assessed RoB from

- ☑ unconcealed allocation, *and*
- ☑ lack of blinding of patients and assessors when assessing outcomes (unnecessary for objective outcomes such as all-cause mortality)

For Yes, must also have assessed RoB from:

- ☑ allocation sequence that was not truly random, *and*
- ☑ selection of the reported result from among multiple measurements or analyses of a specified outcome

☑ Yes
☐ Partial Yes
☐ No
☐ Includes only NRSI

NRSI

For Partial Yes, must have assessed RoB:

- ☑ from confounding, *and*
- ☑ from selection bias

For Yes, must also have assessed RoB:

- ☑ methods used to ascertain exposures and outcomes, *and*
- ☑ selection of the reported result from among multiple measurements or analyses of a specified outcome

☑ Yes
☐ Partial Yes
☐ No
☐ Includes only RCTs

10. Did the review authors report on the sources of funding for the studies included in the review?

For Yes

- ☑ Must have reported on the sources of funding for individual studies included in the review. Note: Reporting that the reviewers looked for this information but it was not reported by study authors also qualifies

☑ Yes
☐ No

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?

RCTs

For Yes:

- ☑ The authors justified combining the data in a meta-analysis
  - ☑ AND they used an appropriate weighted technique to combine study results and adjusted for heterogeneity if present.
  - ☑ AND investigated the causes of any heterogeneity

☑ Yes
☐ No
☐ No meta-analysis conducted

For NRSI

For Yes:

- ☐ The authors justified combining the data in a meta-analysis
  - ☐ AND they used an appropriate weighted technique to combine study results, adjusting for heterogeneity if present
  - ☐ AND they statistically combined effect estimates from NRSI that were adjusted for confounding, rather than combining raw data, or justified combining raw data when adjusted effect estimates were not available
  - ☐ AND they reported separate summary estimates for RCTs and NRSI separately when both were included in the review

☐ Yes
☐ No
☑ No meta-analysis conducted

12. If meta-analysis was performed, did the review authors assess the potential impact of RoB in individual studies on the results of the meta-analysis or other evidence synthesis?

For Yes:

- ☐ included only low risk of bias RCTs
- ☑ OR, if the pooled estimate was based on RCTs and/or NRSI at variable RoB, the authors performed analyses to investigate possible impact of RoB on summary estimates of effect.

☑ Yes
☐ No
☐ No meta-analysis conducted

13. Did the review authors account for RoB in individual studies when interpreting/ discussing the results of the review?

For Yes:

- ☐ included only low risk of bias RCTs
- ☑ OR, if RCTs with moderate or high RoB, or NRSI were included the review provided a discussion of the likely impact of RoB on the results

☑ Yes
☐ No

14. Did the review authors provide a satisfactory explanation for, and discussion of, any heterogeneity observed in the results of the review?

For Yes:

- ☐ There was no significant heterogeneity in the results
- ☑ OR if heterogeneity was present the authors performed an investigation of sources of any heterogeneity in the results and discussed the impact of this on the results of the review

☑ Yes
☐ No

15. If they performed quantitative synthesis did the review authors carry out an adequate investigation of publication bias (small study bias) and discuss its likely impact on the results of the review?

For Yes:

- ☑ performed graphical or statistical tests for publication bias and discussed the likelihood and magnitude of impact of publication bias

☑ Yes
☐ No
☐ No meta-analysis conducted

AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both

16. Did the review authors report any potential sources of conflict of interest, including any funding they received for conducting the review?

For Yes:

- ☑ The authors reported no competing interests OR
- ☐ The authors described their funding sources and how they managed potential conflicts of interest

☑ Yes
☐ No

To cite this tool: Shea BJ, Reeves BC, Wells G, Thuku M, Hamel C, Moran J, Moher D, Tugwell P, Welch V, Kristjansson E, Henry DA. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ. 2017 Sep 21;358:j4008.

Supplementary Material 4. Characteristics of included intervention studies

First author, year (setting)	Study Design	Participants	Intervention (Description and Dose)	Control	Outcomes	Results
Ackley-Holbrook, 2016 (USA)	Pre Post	Severe VI or blindness. Recruited through advocacy organizations, online discussion groups and communities, word-of-mouth. Aged ≥ 18yrs. Mean age = 47.9 ± 11.5 yrs. % Males = UNK n = 21	Walking program; 8 weeks, increasing daily step count by 1000 above baseline, progressively higher targets every 2 weeks	Baseline step count	Daily step count (by pedometer), resting heart rate, blood pressure, body mass, % body fat, waist circumference, lipids	Significant increase in steps per day; (baseline 4925 ± 2233 v post 8772 ± 2916, p<0.01). No significant differences in other measures. Reported improvements in cardiovascular endurance and productivity (93%), mood and mental health (73%), outlook on life, self confidence and functional mobility (67%).
Campbell, 2005 (NZ)	RCT	Visual acuity of 6/24 or worse. Recruited via register for the blind, hospital outpatient clinics, private ophthalmology practice. Living in community. Aged ≥75. Mean age = 83.6 ± 4.8 yrs % Males = 32% n = 391	Four groups; 1) Otago exercise program (Muscle strengthening and balance retraining exercises that progress in difficulty) and walking plan; 5 home visits from a physiotherapist, 3 X 30min per week of exercises plus walking twice a week. n=97 2) Home safety program (Home visit to identify hazards and provision of recommendations to prevent falls). n=100 3) Exercise and home safety program. n=98 4) Control (social visits). n = 96	Two social visits during the first six months	Number of falls and fall related injuries	15% more falls observed in the exercise program (incidence rate ratio = 0.59 [CI 0.42-0.83] v 1.15 [CI 0.82-1.61], however a higher level of adherence led to fewer falls (p=0.001). 41% fewer falls in the home safety program. One year of follow up.
Chen, 2012 (HK)	RCT	Low vision (6/18 - 3/60) and blind (3/60 or worse). Living in a residential care home. Aged ≥ 70. Mean age = 85.5 ± 6.9 yrs (experimental) and 82.9 ± 7.5 yrs (control) % Males = UNK n = 40	Modified 8-form Yang style Tai Chi, emphasizing multi-directional weight shifting, head and trunk rotation and awareness of body alignment; 1.5 hours, 3 times a week, for 16 weeks. n = 21 in intervention	Music percussion activity (djembe i.e. drumming)	Knee proprioception, muscle strength (in knee extensors and flexors), balance	Experimental group showed significant improvements in knee proprioception (percentage change of absolute angle error = -25.9 ± 28.8% v 4.2 ± 30.7%, p=0.032) and balance control (greater percentage change in visual ratio (58.1 ± 41.9% v -1.6 ± 29.4%, p=0.006) and vestibular ratio (32.5 ± 40.2% v -17.8 ± 56.8%, p=0.048). Intention to treat analysis.
Cheung, 2008 (HK)	RCT	No light perception or VI of 6/120 or worse in better eye with corrective device. Living in care and attention homes. Aged ≥ 65. Mean age = 83 ± 4.7 yrs (experimental) and 84 ± 6.5 yrs (control) % Males = 0%	Structured, individually tailored exercise program designed by a physiotherapist, including warm up, lower limb strengthening exercises (increasing in repetitions and weights), balance exercises. Plus routine group physical activity. 3 X 45 min per week, for 12 weeks n = 27 in intervention.	Routine group physical activity only in care home.	Balance and muscle strength.	Significant improvements in BBS (9.4%, p<0.000), TUG (decrease of 4.7 sec, p<0.0003) and CST (decrease of 2.35 sec, p=0.047)

		n = 50				
Gleeson, 2015 (AUS)	RCT	Participants recruited from Guide Dogs Australia. Aged ≥ 50. Mean age = 75 ± 11 yrs. % Males = 29% n = 120	Alexander Technique, 1 X 30 min lesson per week, for 12 weeks, plus usual care. n = 60 in intervention.	Usual care from Guide Dogs Australia.	Short Physical Performance Battery (sit-to-stand, 4m walk test, standing balance test). Postural sway tests, maximal balance range and number of falls.	No statistically significant improvements in primary outcomes at 3 or 12 months between groups. Intervention group reduced postural sway on a firm surface (eyes open) at 3mths (-29.59mm, P<0.01).
Gleeson, 2017 (AUS)	RCT	As per Gleeson 2015	As per Gleeson 2015,	As per Gleeson 2015	Social and emotional wellbeing	No statistically significant improvements at 3 or 12 months. Emotional subscale approached significance (p=0.06) in favor of intervention at three mths.
Hackney, 2015 (USA)	RCT	VI in range 20/30 – 20/632. Recruited from Medical Centre, Senior Independent Living communities, community senior centres. Mean age = 79.3 ± 11 yrs % Males = 47% n = 32	Adapted Tango Classes, 2 X 1.5 hours per week, for 10-12 weeks (total 30 hours). n = 14 Tango intervention.	FallProof Program	Balance, Mobility, Gait speed and quality-of-life.	Tango and FallProof groups showed improvements on BBS (p=0.001). SOT scores improved by 14% in Tango group and 22% in FallProof. Tango group significantly improved on 6MWT (p=0.016), cognitive-TUG(p=0.03) and gait (p<0.001). Last observation carried forward analysis.
Jeter, 2012 (USA)	Pre Post	Visual field <20 deg and/or visual acuity < 20/200. Recruited from Low Vision Clinic of tertiary hospital and local community based listings. Mean age = 46 ± 12 yrs. % Males = 30% n = 10	Ashtanga-Based Yoga (AYT), 1 X orientation session, 1 class per week and 2 sessions per week at home, for 8 weeks.	None	Sleep, anxiety, depression, stress, balance, respiratory rate, mindfulness, balance	Improvements observed in all pre-post measures (descriptive analysis only). Exit surveys showed 5/8 reported reduced stress, 3/8 reported improved sleep. 7/8 reported improved relaxation and focus. 8/8 expressed an interest in a yoga program like this in the future.8/8 subjects were extremely or mostly satisfied with program.
Jeter 2015 (USA)	RCT	Corrected visual acuity worse than 20/200 and/or visual field less than 20 deg in diameter (legal blindness). Recruited from Low Vision Clinic of tertiary hospital. Mean age = 55 ± 17 yrs (experimental) and 55 ± 10 yrs (control) % Males = 29% n = 21	Ashtanga-Based Yoga (AYT), 1 X orientation session, 1 class per week and 2 sessions per week at home, for 8 weeks. n = 11 in intervention	Waitlist Control	Postural stability, balance, physical function	Absolute values of mean total velocity significantly increased in AYT group (Eyes Open; t(8)=-3.66, p=0.01 and Eyes Closed; t(8)=-3.90, p=0.01). Significant baseline post AYT increase in somatosensory contribution to balance SI velocity (Eyes Open; t(8)=-2.42, p=0.04 and Eyes Closed; t(8)=-3.96, p=0.01). Significant increase in vestibular contribution to balance (t(8)=-2.47, p=0.04). Significant increase in one leg stand (z=-2.10, p=0.04), chair sit and reach (z=-2.22, p=0.01), and 30s chair stand (z=-1.98, p=0.05) following AYT program. No changes in control group.
Kingston, 2018 (USA)	Pre Post	No definition of blindness reported. Recruited from Blind Centre. Mean age = 80 yrs. % Males = 88% n = 24	Matter of Balance program (CBT and exercise training in 6 of 8 sessions; Tennstedt, 1998). 2 X 2 hours per week for 4 weeks.	None	Mobility and balance	Mean decrease of 2.15 sec on TUG, small increase in total POMA (1.5 points)
Kovács, 2012 (Hungary)	RCT	Visual acuity 20/30-20/400. Recruited from National Institution for Blind People. Aged ≥ 60 years and over.	Multimodal program - balance and strength exercises based on Otago Exercise Program, using increasing weights. Included 20-30min/day walking program. 30min X 2 week	Standard osteoporosis program alone (4Xwk).	Balance, everyday living activities, mobility, falls	Significant improvements in experimental group pre and post intervention (BBS 41.81 ± 7.52 v 45.09 ± 7.41 p=0.036, TUG 20.72±4.87 v 17.93±4.96 p<0.005). TUG time differed significantly between experimental and control (p=0.001). Number of falls = 22.

		Mean age = 68.7 ± 6.9 yrs (experimental) and 69.7 ± 6.5 yrs (control). % Males = 0% n = 41	multimodal exercise program + 2 X week standard osteoporosis program, for 6 months. n = 21 in intervention			Significantly shorter time to first fall in the control group (15 wks. V 19 weeks, p = 0.049).
Larsson, 2006 (Sweden)	Pre Post	Visual acuity of less than 0.05 in best eye or visual field less than 5 deg. Recruited from Low Vision Clinic. Of working age. Mean age = 52.3 ± 11.4 yrs % Males = 14% (of final participants) n = 8	Body awareness exercises and dance based training. 75min X 2 sessions week, for 8 weeks.	None	Balance, functional reach, functional balance, mobility, gait speed, Activity scale	Statistically significant improvements observed in; Functional reach = 6/7 TUG = 1/7 Max. Gait speed = 2/7 One leg stance (left) = 3/7 One leg stance (right) = 2/7 Max. Step length = 5/7
Miszko, 2004 (USA)	Pre Post	Recruited from local rehabilitation centre. Mean age = 52.6 ± 12.8 yrs. % Males = 70% n = 10	Tai Chi Classes. 2 X 1 hour, per week for 8 weeks, 15min per day outside of class, plus regular orientation and mobility training.	None	Muscular strength, work and power of knee; balance; functional reach and quality of life	Improvements seen in muscular strength (flexion 16.5%, extension16.9%), power (flexion 30%, extension 6.8%), and work (flexion 17.7%, extension 17.1%), small change in functional reach (0.75%) and BBS (2%), improvement in single stance time (6.3%). Improvement in frequency, independence and satisfaction with performing mobility tasks after tai chi.
Ponchillia, 1992 (USA)	Pre Post	Congenital total blindness. Recruited from University. Aged 24-37 yrs. % Males = 0% n = 3	Aerobics sessions led by trained instructor including high and low impact movements. 2 X 50 minutes per week, for 7 weeks.	None	Skinfolds, abdominal muscle strength and endurance, flexibility, heart rate, accuracy of performing tasks, step test.	Favorable changes in fitness based on step test, abdominal strength and endurance (24% mean increase on sit up test), body fat (mean 3.5% decrease) and accuracy of performance.
Salari, 2013 (Iran)	Pre Post	Blind athletes. Mean age = 22.4 ± 5.4 yrs. % Males = 0 % n = 30	Core stability training program. Approximately 3 X 1hr per week (every two days), for 8 weeks	None	Balance (measured by Flamingo Test and Y balance)	Significant increase in static and dynamic balance in anterior direction, internal posterior, external posterior and total balance.
Surakka, 2008 (Finland)	Pre Post	Partially sighted, blind or deaf-blind individuals. Mean age = 54 ± 9.9 yrs. % Males = 33% (of final participants) n = 27	Physical training including movements to improve balance, coordination, relax neck and shoulder muscles. 60 minutes 3 X per week for 5-6 weeks.	None	Physical condition, mental state and balance.	Self reported improvements in physical condition (22/24), mental state (21/24) and balance (11/24). Main motivators were better physical condition (21/24) and peer group (12/24)
Surakka, 2011 (Finland)	RCT	Partially sighted (best corrected visual acuity < 0.3) or blind (visual acuity < 0.1, or visual field < 10 deg with glare and hemeralopia). Recruited from Rehabilitation Services at a tertiary hospital. Mean age = 55 ± 9.0 yrs (experimental) and 57 ± 7.2yrs (control). % Males = 45% n = 29	Physical training designed for VI and deaf-blind persons to improve balance, posture, coordination, tense neck and shoulder muscles, and loss of spinal rotation and reciprocal arm swing. 60 minutes 3 X per week for 5-6 weeks. N=15 in intervention	No intervention	Flexibility	Significant improvement in flexibility of trunk in the experimental v control group (p=0.0068).

Waterman, 2016 (UK)	RCT	Binocular visual acuity > 0.6, Snellen equivalent = 6/24 and/or moderate visual field loss (>20% of the test locations in a binocular Esterman test). Recruited from the community. Mean age = 81.4 ± 8.6 yrs. % Males = 35% n = 49	Home Safety Arm (occupational therapist discussion with participants and action plan to alter environment to reduce risk of falls). Home exercise program arm (based on Otago Exercise Program involving strength and balance exercises in addition to walking). 30min X 3 times per week plus walking X 2 times per week, for 6 months. n = 17 in intervention	Usual care plus social visits	Number of falls, fear of falls, adherence rates, quality of life	No statistically significant differences.

Abbreviations: AUS = Australia, AYT = Ashtanga-Based Yoga, BBS = Berg Balance Score, CST = Chair Stand Test, HK = Hong Kong, NZ = New Zealand, POMA = Performance Oriented Mobility Assessment, RCT = Randomized Controlled Trial, SOT = Sensory organization test, 6MWT = Six minute walk test, TUG = Timed Up and Go, UK = United Kingdom, USA = United States of America, VI = visual impairment.

PRISMA 2009 Checklist

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METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	7
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8-9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8-9
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	NA
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-15
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	17-18
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Fig 2
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Fig 2
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	18
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	NA
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	19-22
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	21-22
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	22
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	23

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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