**A SYSTEMATIC REVIEW AND META-ANALYSIS OF EXERCISE
INTERVENTIONS AND USE OF EXERCISE PRINCIPLES TO REDUCE
FEAR OF FALLING IN COMMUNITY-DWELLING OLDER ADULTS**

by

Chengying Feng

A thesis submitted to the Department in Rehabilitation Science

In conformity with the requirements for

the degree of Master of Science

Queen's University

Kingston, Ontario, Canada

(February 2022)

Copyright © Chengying Feng, 2022

Abstract

Fear of falling (FOF) contributes to activity restriction and increases fall risks and institutionalization among older adults. Exercise interventions are associated with a reduction in FOF. Adhering to exercise principles and adopting proper exercise parameters are fundamental to optimizing the effectiveness of exercise interventions. The objectives of this thesis were to describe FOF exercise interventions in community-dwelling older adults to inform future programs, evaluate the extent to which these interventions followed the exercise principles and reported exercise parameters, and finally quantify the effect of these interventions on reducing FOF.

Randomized controlled trials (RCTs) of FOF exercise interventions in older adults (≥ 65 years) were identified from MEDLINE, Embase, PsycINFO, and CINAHL databases from inception to 2020. Two reviewers independently screened and assessed the relevant literature, and a third reviewer was engaged to resolve any conflicts. The methodological quality of RCTs was assessed using the PEDro scale. The qualitative data were narratively synthesized, and a random-effect model was used in the meta-analysis. Sensitivity analyses were carried out to examine the impact of trials with small sample sizes and a high risk of bias on the findings.

Seventy-five RCTs were included in this review. Most trials with a significant effect on FOF used multicomponent exercises and group-based interventions, moderate intensity, three-times-per-week frequency for 12 to 16 weeks, and 30 to 60 minutes for each exercise session. With regard to reporting exercise principles, specificity was reported in 92% of trials, progression in 72%, reversibility in 32%, overload in 31%, diminishing return in 21%, and initial value in only 8% of trials. For exercise parameters, 97% of RCTs reported exercise type, 89% reported frequency, and 85% reported time. Only 25% of trials reported the intensity of exercises. The pooled effect of exercise interventions on FOF reduction among all included studies was a standard mean difference of -0.34 (95% CI = -0.44 to -0.23). The sensitivity analysis showed that the pooled effect size decreased after removing trials with small

sample sizes (-0.25; 95% CI = -0.37 to -0.13) and with fair methodological quality (-0.22; 95% CI = -0.36 to -0.8), but the results were still significant.

This study showed a significant small-to-moderate effect size of exercise interventions in reducing FOF among community-dwelling older adults. Most exercise principles and the intensity of exercises were not adequately reported in included trials. These inadequate reports could undermine efforts to examine the optimal dosage for exercise prescription. Researchers must give more attention to designing and reporting components of therapeutic exercise programs to facilitate evidence-based practice.

Co-Authorship

This thesis presents the research conducted by Chengying Feng under the supervision of Dr. Mohammad Auais. Tony Adebero facilitated the screening titles, abstracts and full texts, as well as the data extraction process. Dr. Vincent DePaul and Kathleen Norman provided constructive feedback and editorial support. Dr. Afshin Vafaei was consulted for his expertise in statistical analyses. The authorship and the related publication is as follows:

Related published manuscript:

Feng C, Adebero T, DePaul VG, Vafaei A, Norman KE, Auais M. A Systematic Review and Meta-Analysis of Exercise Interventions and Use of Exercise Principles to Reduce Fear of Falling in Community-Dwelling Older Adults. *Physical therapy*. 2022 Jan;102(1):pzab236.

Volume 102, Issue 1
January 2022
(In Progress)

Comments (0)

[< Previous](#) [Next >](#)

A Systematic Review and Meta-Analysis of Exercise Interventions and Use of Exercise Principles to Reduce Fear of Falling in Community-Dwelling Older Adults

[Get access >](#)

Chengying Feng , Tony Adebero, Vincent G DePaul, Afshin Vafaei, Kathleen E Norman, Mohammad Auais

Physical Therapy, Volume 102, Issue 1, January 2022, pzab236,
<https://doi.org/10.1093/ptj/pzab236>

Published: 08 October 2021 [Article history ▾](#)

Cite Permissions Share ▾

Abstract

Objective

Fear of falling (FOF) contributes to activity restriction and institutionalization among older adults, and exercise interventions are linked to reduction in FOF. Adhering to exercise principles and adapting optimal exercise parameters are fundamental to optimizing the effectiveness of exercise interventions. The purpose of this review was to describe FOF exercise interventions in community-dwelling older adults, evaluate the extent to which these interventions followed the exercise principles and reported exercise parameters, and quantify the effect of these interventions on reducing FOF.

Methods

Randomized controlled trials (RCTs) of FOF exercise interventions in older adults (≥ 65 years) were identified from 4 databases. The methodological quality of RCTs was assessed using the Physiotherapy Evidence Database scale. A random-effect model was used in the meta-analysis.

Seventy-five RCTs were included in this review. With regard to reporting exercise principles, specificity was reported in 92% of trials, progression in 72%, reversibility in 32%, overload in 31%, diminished return in 21%, and initial value in 8%. For exercise parameters, 97% of RCTs reported exercise type; 89%, frequency; and 85%, time. Only 25% reported the intensity. The pooled effect of exercise interventions on FOF among all included studies was a standard mean difference of -0.34 (95% CI = -0.44 to -0.23).

Conclusion

This study showed a significant small to moderate effect size of exercise interventions in reducing FOF among community-dwelling older adults. Most exercise principles and intensity of exercises were not adequately reported in included trials.

Impact

These inadequate reports could undermine efforts to examine the optimal dosage for exercise prescription. More attention must be given to designing and reporting components of therapeutic exercise programs to facilitate evidence-based practice.

Keywords: [Accidental Falls](#), [Aged](#), [Exercise Therapy](#), [Geriatrics](#)

Issue Section: [Review](#)

Acknowledgements

Words are not enough to express my gratitude to those important persons who stood next to me as I pursued my master's degree at Queen's University and completed this thesis. Nevertheless, I would like to take this opportunity to express my deepest appreciation to people who have contributed to the conclusion of my master's journey.

Dr. Mohammad Auais, you are the most important part of this undertaking. Without your generosity and kindness in providing me with a second chance for admission into the master's program, I would not have set out at all. The thesis would not be possible without your endless support, patience, and guidance. Your faith in me has encouraged me to try things I would not be confident to try on my own such as the MITACS funding application and conference presentations. Your trust in my capabilities in completing high-quality research tasks has provided me with great opportunities to develop my academic skills. As the adage goes: "Give a person a fish and they will eat for a day; teach them how to fish and they will eat for a lifetime". You have seized each possible opportunity to coach me to become a better researcher. I remember during our meetings, whenever I ask you a question, you would not give me a straightforward and easy answer, instead, you would always encourage me to find the answer on my own, and then you would step in when it was necessary. I will be always mindful of what you have taught me whenever I encounter challenges in my future academic career.

I would also like to submit my special appreciation to Drs. Vincent DePaul and Kathleen Norman for their constructive feedback, expertise, and guidance, and to Dr. Afshin Vafaei for guiding and supporting me in conducting statistical analyses.

Last but not the least, I wish to give my most sincere thanks to my family for their unconditional love and support and my friend Dr. Amir Rasooli who has been a great company in the past two years, providing academic support during difficult times and valuable tips on how to thrive in academia.

Table of Contents

Abstract	ii
Co-Authorship	iv
Acknowledgements	vi
List of Figures	x
List of Tables.....	xi
List of Abbreviations.....	xii
Chapter 1 Introduction	1
1.1 Research Statement	1
1.2 Principles of Exercise Training and Exercise Prescription Framework.....	3
1.2.1 Exercise Is Medicine	3
1.2.2 Distinctions of Physical Activity, Physical Exercise, Physical Training, and Exercise Prescription.....	4
1.2.3 Principles of Exercise Training	5
1.2.3 FITT Exercise Prescription Framework.....	6
1.3 Purpose	7
1.4 Dissertation Overview	7
1.5 References	9
Chapter 2 Literature Review	12
2.1 Introduction	12
2.2 Conceptualization and Outcome Measures of FOF	12
2.2.1 Conceptualization.....	12
2.2.2 Outcome Measures	14
2.3 Epidemiology	16
2.4 Risk Factors and Consequences of FOF	16
2.4.1 Risk Factors.....	16
2.4.2 Consequences of FOF	20
2.5 FOF Interventions	22
2.6 References	29
Chapter 3 Methods	34
3.1 Overview	34
3.2 Data Sources and Search Strategy.....	35
3.3 Study Selection.....	35

3.4 Data Extraction and Quality Assessment.....	37
3.5 Data Synthesis and Analysis	39
3.6 References	42
Chapter 4 Results	44
4.1 Study Selection.....	44
4.2 Study Characteristics.....	45
4.3 Reporting of Principles of Exercise Training.....	55
4.4 Reporting of FITT Components and Adherence.....	55
4.5 Rating of the Methodological Quality of Included RCTs	58
4.6 Exercise Prescription.....	61
4.7 Meta-Analysis	76
4.7.1 Effectiveness of Exercise Interventions for FOF	76
4.7.2 Subgroup Analysis	76
4.7.3 Sensitivity Analysis.....	82
4.7.4 Publication Bias.....	84
4.8 References	85
Chapter 5 Discussion.....	90
5.1 Reporting of Principles of Exercise Training and FITT Components	90
5.1.1 Specificity.....	90
5.1.2 Progression	90
5.1.3 Overload	91
5.1.4 Initial Value.....	92
5.1.5 Diminishing Return	92
5.1.6 Reversibility	93
5.1.7 FITT Components	93
5.2 The Overall Effect of FOF Exercise Intervention.....	94
5.3 Comparing Results with Previous Reviews on FOF Intervention	95
5.3.1 FOF Exercise Interventions.....	95
5.3.2 Other Types of FOF Interventions	96
5.4 Implications for Future Research, Practice and Policy	98
5.4.1 Research Implications	98
5.4.2 Practice Implications	99
5.4.3 Policy Implication	99
5.5 Strengths and Limitations.....	100

5.6 Conclusion.....	101
5.7 References	102
Appendix A Search History from EMBASE	106
Appendix B Search History from PsycINFO.....	107
Appendix C Search History from Medline	108
Appendix D Search History from CINAHL	109
Appendix E Excluded Studies and Reasons for Exclusion	110
Appendix F Subgroup Analyses for Studies Using Change-from-baseline Values.....	116
Appendix G PRISMA Checklist	121
Appendix H AMSTAR2.....	124

List of Figures

Figure 1: Flow chart of the study selection process	45
Figure 2: Reporting of principles of exercise training	55
Figure 3: Reporting of FITT components and adherence	56
Figure 4: The pooled effect of exercise interventions on FOF using post-intervention data.....	76
Figure 5: Subgroup analyses by outcome measures using post-intervention data.....	78
Figure 6: Subgroup analyses by types of exercise interventions using post-intervention data.....	79
Figure 7: Subgroup analyses by the duration of intervention using post-intervention data.....	80
Figure 8: Subgroup analyses by whether FOF is primary or secondary outcome measures using post-intervention data.....	81
Figure 9: Subgroup analyses by whether the intervention was individual or group-based using post-intervention data.....	82
Figure 10: The pooled effect of exercise interventions on FOF using change-from-baseline values (n=52)	83
Figure 11. Funnel plot using post-intervention data	84

List of Tables

Table 1: Effects of types of FOF interventions	22
Table 2: Rating the reporting of principles of exercise training, FITT components and adherence.....	38
Table 3: Study characteristics	47
Table 4: Reporting of principles of exercise training and FITT	56
Table 5. PEDro scores.....	59
Table 6: The number (%) of trials meeting each criterion of PEDro scale	61
Table 7: Exercise prescription characteristics	63
Table 8: Summary of main findings in included studies.....	70

List of Abbreviations

ABC	Activity-specific Balance Scale
ACSM	American College of Sports Medicine
ADL	Activities of Daily Living
AMOB/ALL	A Matter of Balance Volunteer Lay Leader
APA	Anticipatory Postural Adjustments
CBT	Cognitive Behavioral Therapy
CERT	Consensus on Exercise Reporting Template
CI	Confidence Interval
CONbal	A measure of balance confidence
3D	Three-dimensional
EIM	Exercise Is Medicine
EP	Exercise Principles
FaME	Falls Management Exercise
FES	Falls Efficacy Scale
FES-I	Fall Efficacy Scale-International
FFABQ	Fear of Falling Avoidance Behavior Questionnaire
FFQ	Fear of Falling Questionnaire
FITT	Frequency, Intensity, Time, and Type of exercise
FOF	Fear of Falling
GFFM	Geriatric Fear of Falling Measure
IADL	Instrumental Activities of Daily Living
ME	Maximum Exertion
MeSH	Medical Subject Headings
MFES	Modified Fall Efficacy Scale
MW	Maximum Workload
OEP	Otago Exercise Programme
OR	Odds Ratio
PEDro	Physiotherapy Evidence Database
RENEW	Resistance Exercise via Negative, Eccentrically-induced Work
RCT	Randomized Controlled Trials
1RM	1 Repetition Maximum

ROM	Range of Motion
RPE	Rating of Perceived Exertion
SAFE	Survey of Activities and Fear of Falling in the Elderly
SF-36	36-Item Short Form Survey
SMD	Standardized Mean Difference
TUG	Timed Up and Go
USA	United States of America
VAS	Visual Analog Scale
UK	United Kingdom

Chapter 1

Introduction

1.1 Research Statement

Approximately one-third of older Canadians fall at least once each year.¹ Falls are the number one cause of injury-related hospitalization and premature death among Canadians over 65 years of age.² Falls and their related injuries threaten older individuals' psychological and physical health, such as the increased risk of fear of falling and depression, reduced quality of life, and loss of independence.² Falls also place significant pressure on government finances and the healthcare system. According to the Public Health Agency of Canada, an estimated 2 billion dollars in direct healthcare costs are associated with senior falls annually.² The costs will rise exponentially as the ageing population (65+) in Canada continues to grow faster, from 6.8 million in 2020 to 11 million by 2036.²

Despite the severe consequences of falls at both individual and social levels, there have been issues related to older adults' perception of the risk of falling. Over 30% of older Canadians reported being concerned about a future fall, with a third of them having had fall experiences in the previous year.³ Exaggerated concern about falling, termed "Fear of Falling" (FOF), is a risk factor of falling itself and associated with social and physical activity restrictions. Around 44% of older Canadians with FOF reported that they had ceased participating in some of the activities they used to enjoy because of their falling concerns.³ The FOF induced activity restriction promotes a downward spiral of physically diminished function and falls, which in turn aggravates FOF.^{4,5} In addition to the physical impact, FOF leads to adverse psychosocial outcomes such as low self-efficacy,⁶ poor life satisfaction,⁷ and high risks of anxiety,⁸ depression⁸, and social isolation.⁹

Due to multifactorial causes (e.g., poor balance and depression) and biopsychosocial impacts (e.g., loss of independence and social isolation) of FOF in older adults, various types of FOF interventions have been developed to address this complex issue. These interventions include (1) exercise interventions such as balance, strength, and Tai Chi exercises, (2) psychological interventions including cognitive behavior therapy and education, and (3) other interventions such as environmental modification and nutritional supplementation.¹⁰ Exercises appear to be a single-factor intervention that is effective and broadly investigated among all FOF interventions.¹¹ In particular, research has shown that exercise interventions can enhance older adults' falls-related self-efficacy and balance confidence by improving their muscle strength, mobility, endurance, gait patterns, and static and dynamic balance. For example, community-based exercise programs, such as Tai Chi,^{12,13} balance and resistance training,¹⁴ and multicomponent home-based exercise programs,¹⁵ have shown effectiveness in increasing balance confidence and reducing FOF. Several systematic reviews provide an insight into the influence of various exercise interventions on FOF.^{11,16-18} For example, a systematic review and meta-analysis¹¹ that included 30 trials found a small to moderate effect size of exercise interventions on reducing FOF immediately after intervention in older adults.

However, FOF exercise interventions vary across studies, and there is no unified consensus on the recommendations of type and “dosage” of FOF exercise interventions (i.e., intensity, duration, and frequency) for community-dwelling older adults. Experts and researchers often recommend exercise as an essential intervention for preventing certain health conditions such as falls and FOF in community-dwelling older adults. However, they do not provide guidelines on precise exercise prescription for those purposes.¹⁹

In the field of rehabilitation, exercise prescription is a process to develop a proper regimen with a specific purpose through evaluating and interpreting clinical information.²⁰ To enhance the chance of successful training effect and minimize side effects, exercise prescription

has to follow well-established principles of exercise training, including specificity, progression, overload, initial value, reversibility and diminishing return.²¹ Disregarding these principles may lead to an inadequate intervention design, which in turn can put studies at risk of drawing unreliable conclusions regarding their outcomes of interest. Furthermore, frequency, intensity, time, and type of exercise (FITT) are the main variables that can be manipulated to assure the application of exercise principles and maximize the benefit of exercise training.²¹ Arnold et al. point out that there is a need for a clear understanding of optimal frequency, intensity, type and duration of exercise for fall prevention programs.²² As part of exercise training studies, both applications of exercise principles and FITT components should be reported so that the peer reviewers can critically appraise the effectiveness of exercise interventions and replicate the interventions in clinical settings. Without this information, clinicians attempting to implement an effective, evidence-based exercise program for older adults with FOF would encounter an enormous challenge. Although numerous reviews have examined the effect of FOF exercise interventions,²³ no reviews have examined the measures of exercise prescription or taken them into account in their appraisal. This gap has the potential to create risks for knowledge mobilization. When the actual exercise dosage is unknown, there is a risk that exercise programs that were shown to be effective may be rendered ineffective with low fidelity in their implementation to the original programs. Therefore, an in-depth investigation of FOF exercise interventions in the current literature based on the established principles of exercise training and exercise prescription framework is key to scientific reproducibility and successful translation of evidence to clinical practice.

1.2 Principles of Exercise Training and Exercise Prescription Framework

1.2.1 Exercise Is Medicine

Exercise as a medicine is an old concept but only gained acceptance in the 20th century. Hippocrates in ancient Greece was among the first to advocate exercise, stating: “if we could give

every individual the right amount of nourishment and exercise, not too little and not too much, we would have found the safest way to health”.²⁴ It was not until the 19th century that a physician named Mckenzie began considering exercise as a technique to rehabilitate people with disabling injuries.²⁵ Gradually, exercise specialists became aware of the rationales for medically directed exercise in a wide array of conditions. Extensive evidence supports exercise as playing a significant role in the primary and secondary prevention of cancer,²⁶ hypertension,²⁷ coronary artery disease,²⁸ depression,²⁹ osteoporosis,³⁰ and dementia.³¹ In November 2007, Exercise Is Medicine (EIM) was initiated by the American College of Sports Medicine (ACSM) in conjunction with the American Medical Association. Specifically, the missions of EIM were to ensure physical activity assessment and promotion as a standard of medical care and encourage physicians and other healthcare providers to refer patients to qualified exercise professionals. EIM has since expanded globally to more than 40 countries in just two years.³²

1.2.2 Distinctions of Physical Activity, Physical Exercise, Physical Training, and Exercise Prescription

The terms “physical activity”, “physical exercise”, “exercise training”, and “exercise prescription” describe different concepts that are sometimes used interchangeably. **Physical activity** refers to any body movements that involve skeletal muscle contraction and energy expenditure.³³ Physical activity consists of a broad range of household, occupational, recreational, and conditioning activities. **Physical exercise**, however, is a subset of physical activity that is specific, planned, and structured.³⁴ Physical exercise includes various types such as strength, endurance, flexibility, and balance exercises. Physical exercise can be performed casually or repetitively with non-specific or specific goals. A regularly planned and structured exercise to maintain and enhance fitness is a form of **physical training**.³⁴ According to ACSM, **exercise prescription** is a recommended physical activity program that is designed in a systematic and personalized manner, considering the frequency, intensity, time and type of exercise.³⁵ In the field of rehabilitation, exercise prescription is a process of evaluating and interpreting clinical

information and using the principles of exercise training and appropriate dosage to determine whether a regimen is appropriate for achieving the outcomes of interests.³⁶

1.2.3 Principles of Exercise Training

Principles of exercise training (i.e., specificity, overload, progression, initial values, reversibility and diminishing returns) are fundamental components for prescribing an exercise training program because they impact the effectiveness of exercise training.³⁷ Inconsistency in applying principles of exercise training in exercise intervention studies might lead to non-significant results due to the inappropriate exercise prescriptions, resulting in the misinterpretation of the training effect.³⁸ Exercise principles include specificity, progression, overload, progression, initial values, reversibility and diminishing returns. The **specificity** requires us to prescribe an exercise training program that is tailored to a specific organ system(s) or muscle(s) to elicit the desired adaptation(s).³⁴ For example, resistance exercise targeting lower limb muscles is a more appropriate intervention than aerobic exercise for a person who has developed atrophy in lower limb muscles. The **progression** of exercise dose ensures that new adaptations occur when our body has adapted to the previous dosage.³⁴ Progression of exercise training involves increasing any of the FITT components depending on an individual's health status, training response, and training goals. For example, an inactive adult who initiated an aerobic exercise program at a light-to-moderate intensity is recommended to increase exercise time/duration by five to ten minutes per session every one to two weeks over the first four to six weeks of an exercise training program.³⁵ The **overload** refers to an appropriate training stimulus that must exceed the individual's current exercise capacity.³⁴ This stimulus is the proper combination of FITT components. For example, to produce muscle hypertrophy in a new health adult trainee, an intensity of 70-85% of 1RM, eight to 12 repetitions with one to three sets for each muscle or muscle group is recommended by ACSM.³⁵ The **Initial values** indicate that individuals with lower initial values will experience more significant improvements following a

training program than individuals with higher initial values.³⁹ Finally, the principles of reversibility and diminishing return are associated with the long-term effects of exercise training. In respect to **reversibility**, as soon as the exercise stimulus is removed, a de-adaptational process will occur and will eventually return to the baseline fitness level.³⁴ In respect to **diminishing return**, a deceleration of improvements can be expected after a period of time as trainees reach a higher fitness level.³⁹

1.2.3 FITT Exercise Prescription Framework

To achieve therapeutic goals, an exercise prescription resembling a drug prescription should specify the exercise dose.⁴⁰ The essential part of exercise dose consists of exercise parameters. They are frequency, intensity, time, and type of exercises (FITT). **Frequency** gives information on the number of training sessions across a specific time interval.³⁴ They can be performed several times a day or less frequently, perhaps a few times per week. For example, patients after total hip arthroplasty are recommended to perform a range of motion exercise program several times a day. Older adults should perform vigorous exercise no more than three times a week to minimize the risks of injuries and cardiac events. **Intensity** represents the degree of strenuousness or challenge level of a specific exercise or a training session. Intensity is commonly measured by the maximal heart rate, maximal oxygen consumption, metabolic equivalents or rate of perceived exertion.³⁴ **Time or duration** of exercises is a period of a specific exercise or a training session.⁴¹ The time is often indicated by the minutes per session for aerobic exercises, while the number of repetitions and sets is indicative of time for resistance exercises.⁴¹ Exercises can be categorized into different **types** (i.e., aerobic, resistance, flexibility, neuromotor exercise) depending on their effect on physical function.⁴¹ Aerobic or endurance exercise aims at improving cardiovascular function by engaging large muscle groups and consuming more oxygen than the body would while resting. Resistance or strength exercise is any exercise that involves contracting the muscles against an external resistance to increase muscle strength, power,

hypertrophy or endurance. Flexibility exercise stretches muscles, ligaments, or joint capsules to maintain optimal muscle length and joint mobility. Neuromotor exercise integrates several motor skills to target functions of balance, coordination, gait, agility, and proprioception.³⁵ Some exercises combining resistance, neuromotor and flexibility such as Tai Chi, yoga, and Pilates are called three-dimensional (3D) exercises in the present study.

Each FITT component is indispensable when designing and prescribing an exercise training program since all of them together provide a clear structure for the training guideline based on a specific population, medical condition, and outcome of interest. For example, the ACSM recommends that in general older adults (≥ 65 years) should perform 30 to 60 minutes of aerobic exercise with moderate intensity five or more times a week.³⁵

In summary, manipulation of FITT components by following the principles of exercise training is the key to the success of designing and prescribing an effective exercise training program. Meanwhile, using them as criteria to critically appraise the quality of exercise interventions will provide better insight into the actual efficacy of those exercise interventions in studies.

1.3 Purpose

The purposes of this thesis are to (1) describe FOF exercise interventions in community-dwelling older adults that have been reported in the peer-reviewed literature in terms of the extent to which they followed the principles of exercise training and reported FITT components; (2) provide evidence on the magnitude of the effect of exercise interventions in reducing FOF in community-dwelling older adults; (3) explore variables that might impact the effect size of included exercise interventions.

1.4 Dissertation Overview

The thesis consists of five chapters. Chapter 1 is an introduction in which I state the background information, rationales, key concepts and measures of exercise prescription and the

purposes of this thesis. Chapter 2 is a general literature review, in which I provide an overview of FOF conceptualizations, outcome measures, epidemiology, risk factors, consequences, and relevant interventions. Chapter 3 to Chapter 5 are methods, results, and discussion, respectively.

1.5 References

1. Stinchcombe A, Kuran N, Powell S. Report summary-seniors' falls in Canada: second report: key highlights. *Chronic Diseases and Injuries in Canada*. 2014;34(2-3).
2. Public Health Agency of Canada. Seniors' falls in Canada: second report [Internet]. *Ottawa (ON): Public Health Agency of Canada*. 2014. [cited 2021 Dec 4]. Available from: <http://www.phac-aspc.gc.ca/seniors-aaines/publications/public/index-eng.ph>
3. Pearson C, Geran L, St-Arnaud J. Understanding seniors' risk of falling and their perception of risk. *Ottawa: Statistics Canada*. 2014.
4. Bertera EM, Bertera RL. Fear of falling and activity avoidance in a national sample of older adults in the United States. *Health & Social Work*. 2008;33(1):54-62.
5. Jørstad EC, Hauer K, Becker C, Lamb SE, Group P. Measuring the psychological outcomes of falling: a systematic review. *Journal of the American Geriatrics Society*. 2005;53(3):501-510.
6. Tinetti ME, Powell L. Fear of falling and low self-efficacy: a cause of dependence in elderly persons. *Journal of Gerontology*. 1993.
7. Oh E, Hong G-RS, Lee S, Han S. Fear of falling and its predictors among community-living older adults in Korea. *Aging & Mental Health*. 2017;21(4):369-378.
8. van Haastregt JCM, Zijlstra GAR, van Rossum E, van Eijk JTM, Kempen GIJM. Feelings of anxiety and symptoms of depression in community-living older persons who avoid activity for fear of falling. *The American Journal of Geriatric Psychiatry*. 2008;16(3):186-193.
9. Painter JA, Allison L, Dhingra P, Daughtery J, Cogdill K, Trujillo LG. Fear of falling and its relationship with anxiety, depression, and activity engagement among community-dwelling older adults. *The American Journal of Occupational Therapy*. 2012;66(2):169-176.
10. Kruisbrink M, Delbaere K, Kempen GI, et al. Intervention characteristics associated with a reduction in fear of falling among community-dwelling older people: a systematic review and meta-analysis of randomized controlled trials. *The Gerontologist*. 2021;61(6):e269-e282.
11. Kumar A, Delbaere K, Zijlstra G, et al. Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and ageing*. 2016;45(3):345-352.
12. Li F, Harmer P, Chou LS. Dual-task walking capacity mediates Tai Ji Quan impact on physical and cognitive function. *Med Sci Sports Exerc*. 2019;51(11):2318-2324.
13. Iliffe S, Kendrick D, Morris R, et al. Multicentre cluster randomised trial comparing a community group exercise programme and home-based exercise with usual care for people aged 65 years and over in primary care. *Health Technology Assessment*. 2014;18(49):vii.
14. Zhao Y, Chung PK, Tong TK. Effectiveness of a community-based exercise program on balance performance and fear of falling in older nonfallers at risk for falling: a randomized, controlled study. *Journal of Aging & Physical Activity*. 2016;24(4):516-524.
15. van Haastregt JC, Diederiks JP, van Rossum E, de Witte LP, Voorhoeve PM, Crebolder HF. Effects of a programme of multifactorial home visits on falls and mobility impairments in elderly people at risk: randomised controlled trial. *BMJ*. 2000;321(7267):994-998.
16. Kendrick D, Kumar A, Carpenter H, et al. Exercise for reducing fear of falling in older people living in the community. *Cochrane Library*. 2014;2015(11):CD009848-CD009848.

17. Logghe IH, Verhagen AP, Rademaker AC, et al. The effects of Tai Chi on fall prevention, fear of falling and balance in older people: a meta-analysis. *Preventive Medicine*. 2010;51(3-4):222-227.
18. Kruisbrink M, Delbaere K, Kempen GI, et al. Intervention characteristics associated with a reduction in fear of falling among community-dwelling older people: a systematic review and meta-analysis of randomized controlled trials. *The Gerontologist*. 2020;61(6): e269-e282.
19. Haas R, Maloney S, Pausenberger E, et al. Clinical decision making in exercise prescription for fall prevention. *Physical Therapy*. 2012;92(5):666-679.
20. Sasso JP, Eves ND, Christensen JF, Koelwyn GJ, Scott J, Jones LW. A framework for prescription in exercise-oncology research. *J Cachexia Sarcopenia Muscle*. 2015;6(2):115-124.
21. Ammann BC, Knols RH, Baschung P, de Bie RA, de Bruin ED. Application of principles of exercise training in sub-acute and chronic stroke survivors: a systematic review. *BMC Neurology*. 2014;14(1):167.
22. Arnold CM, Sran MM, Harrison EL. Exercise for fall risk reduction in community-dwelling older adults: a systematic review. *Physiotherapy Canada*. 2008;60(4):358-372.
23. Kumar A, Delbaere K, Zijlstra GAR, et al. Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and Ageing*. 2016;45(3):345-352.
24. Hippocrates A. Genuine works of translated from the greek with a preliminary discourse and annotations v. 2. 123456789/1251. 1849.
25. Boerigter RJ. *A history of the American College of Sports Medicine*. The University of Utah; 1978.
26. Hojman P, Gehl J, Christensen JF, Pedersen BK. Molecular mechanisms linking exercise to cancer prevention and treatment. *Cell Metabolism*. 2018;27(1):10-21.
27. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. Exercise and hypertension. *Medicine & Science in Sports & Exercise*. 2004;36(3):533-553.
28. Morris JN. Exercise in the prevention of coronary heart disease: today's best buy in public health. *Medicine and Science in Sports and Exercise*. 1994;26(7):807-814.
29. Harvey SB, Øverland S, Hatch SL, Wessely S, Mykletun A, Hotopf M. Exercise and the prevention of depression: results of the HUNT cohort study. *American Journal of Psychiatry*. 2018;175(1):28-36.
30. Senderovich H, Kosmopoulos A. An insight into the effect of exercises on the prevention of osteoporosis and associated fractures in high-risk individuals. *Rambam Maimonides Medical Journal*. 2018;9(1).
31. Alty J, Farrow M, Lawler K. Exercise and dementia prevention. *Practical Neurology*. 2020;20(3):234-240.
32. Lobelo F, Stoutenberg M, Hutber A. The exercise is medicine global health initiative: a 2014 update. *British Journal of Sports Medicine*. 2014;48(22):1627-1633.
33. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports*. 1985;100(2):126.
34. Herold F, Müller P, Gronwald T, Müller NG. Dose–response matters—a perspective on the exercise prescription in exercise–cognition research. *Frontiers in Psychology*. 2019;10:2338.
35. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription, 8th Ed + ACSM's Certification Review, 3rd Ed*. Philadelphia, PA, USA: Lippincott Williams & Wilkins; 2010.

36. Brody LT. Effective therapeutic exercise prescription: the right exercise at the right dose. *Journal of Hand Therapy*. 2012;25(2):220-232.
37. Cosaburi R. Principles of exercise training. *Chest*. 1992;101(5):263S-267S.
38. Schlagheck ML, Joisten N, Walzik D, et al. Systematic review of exercise studies in persons with multiple sclerosis: exploring the quality of interventions according to the principles of exercise training. *Neurology and Therapy*. 2021;10(2):585-607.
39. Pfister PB, de Bruin ED, Tobler-Ammann BC, Maurer B, Knols RH. The relevance of applying exercise training principles when designing therapeutic interventions for patients with inflammatory myopathies: a systematic review. *Rheumatology International*. 2015;35(10):1641-1654.
40. Sallis R. Exercise is medicine: a call to action for physicians to assess and prescribe exercise. *The Physician and Sportsmedicine*. 2015;43(1):22-26.
41. Mazzeo RS, Tanaka H. Exercise prescription for the elderly. *Sports Medicine*. 2001;31(11):809-818.

Chapter 2

Literature Review

2.1 Introduction

Fear of Falling (FOF) is a multidimensional construct with multifactorial etiology. It has a significant adverse impact on biopsychosocial outcomes of community-dwelling older adults in addition to substantial healthcare utilization and costs.¹ Implementing effective interventions to address this complex issue is, therefore, of vital importance. This chapter is a literature review composed of five main sections. Section one outlines the content of each subsequent section. Section two provides an overview of FOF conceptualizations and outcome measures related to FOF constructs. Section three reviews epidemiological findings on FOF. Section four synthesizes what we know regarding the risk factors and consequences of FOF. Section five outlines the findings about FOF interventions for older adults. Together, the reviews in all these sections facilitate an in-depth understanding of how and why different FOF interventions were developed as well as the mechanisms of various interventions used in reducing FOF. The reviews also help identify the gaps in the current FOF interventions, providing the foundation for this thesis.

2.2 Conceptualization and Outcome Measures of FOF

2.2.1 Conceptualization

FOF has been conceptualized in many ways. Marks and Bebbington in 1970 used “space phobia” to describe patients who had intense fear when standing without visuospatial cues of support nearby.² They also argued that this space phobia was an unrecognized syndrome that was distinct from agoraphobia (excessive fear of certain environments such as open spaces, public transit, and shopping center).² The term “ptophobia” was coined in 1982 to describe a distinct psychological problem characterized by an intense fear of standing or walking following an accidental fall unrelated to

agoraphobia.³ Subsequently, Murphy and Isaacs in 1982 described what they called “post-fall syndrome” as a consequence of fall experience.⁴ However, the post-fall syndrome is different from the concept of FOF in that FOF has been reported among older adults who had never experienced falls.^{5,6}

In 1990, Tinetti, Richman, and Powell operationalized FOF as “low perceived self-efficacy in avoiding falls during essential, nonhazardous activities of daily living.”⁷ However, Tinetti and Powell in 1993 re-defined FOF as “a lasting concern about falling that leads to an individual avoiding activities that he/she remains capable of performing.”⁸ This definition changed the words “low perceived self-efficacy” to “a lasting concern” and introduced the behavior consequence of FOF, which is activity avoidance. Powell et al. later defined FOF as “an individual’s confidence in their ability to maintain balance during activities of daily living”.⁹

The concepts of self-efficacy and balance confidence are based on Bandura’s self-efficacy theory, which posits that a person’s belief or confidence about their capability to perform certain activities impact their behaviors.¹⁰ A person’s belief or confidence, according to Bandura, is based on (1) enactive mastery experience, (2) vicarious experience, (3) verbal persuasion and (4) physiological and affective states.¹⁰ Particularly, older adults’ confidence or beliefs about their ability to avoid falling and maintain balance when performing some physical activities are influenced by (1) their past fall-management experience, (2) their observation of similar others managing their fall experience, (3) other’s verbal encouragement, and (4) physiological feedbacks such as pain and injuries as well as affective states such as mood and anxiety.¹⁰ As a result of the cognitive appraisal process of one’s ability to do an activity, an individual will either participate or avoid a particular activity because of fear. For example, individuals might avoid an activity if they have low confidence in performing it.

The use of falls-related self-efficacy or balance confidence as a proxy of FOF construct has led to fruitful research evidence and encouraged interchangeability across fear/concern/worry about falling in relation to falls-related self-efficacy/balance confidence.¹¹ However, more recent literature underlines that falls-related self-efficacy/balance confidence and fear/concern/worry about falling are associated but distinct constructs with different theoretical origins.¹¹ Falls-related self-efficacy refers to confidence in

one's capability to overcome falls, while fear/concern/worry about falling describes a state of apprehension towards the risk of falls.¹²

Overall, FOF is now dominantly conceptualized in the literature in two ways. First, FOF is an umbrella term that contains cognitive constructs such as self-efficacy and balance confidence and affective constructs such as fear, concern or worries about falling. Second, fear/concern/worry about falling is a theoretically distinct but related construct to falls-related self-efficacy and balance confidence. Despite the difference between these two theoretical conceptualizations of FOF constructs, they are often operationally combined, given that studies have consistently shown high correlations across the components forming FOF.¹³ Therefore, FOF in this thesis refers to an umbrella term including fear/concern/worry about falling and falls-related self-efficacy/balance confidence.

2.2.2 Outcome Measures

Although more than 20 self-reported outcome measures related to FOF were identified in Jorstad et al.'s systematic review,⁵ many are variants of the same measures and assess the same constructs of FOF. Here, the key approaches to FOF measurement based on the different constructs of FOF are reviewed. Several outcome measures have been created to explore the affective construct of FOF including fear, concern or worry about falling.^{5,14} Others draw on the theory of self-efficacy to assess the cognitive construct of FOF, such as falls-related self-efficacy, or balance confidence.^{7,9} Finally, a few measurement tools combine the affective construct with behavioral changes to examine FOF-induced activity avoidance.^{15,16}

The simplest method to measure the affective construct (fear, concern and worry about falling) of FOF is single-item measures including a dichotomous yes/no response, a 4-point Likert-type rating scale and a visual analogue scale for FOF.^{5,17} Some sample single-item questions include “*Are you afraid/worried about falling?*” or “*Do you have a fear of falling?*”. This type of measure may help quickly identify the prevalence of FOF in epidemiology but demonstrates low sensitivity to change in the research and does not measure FOF-related behavior consequences.¹⁸

Grounded in social cognitive theory, two common outcome measures were established based on Bandura's theory of self-efficacy. The first one is the Falls Efficacy Scale (FES), which measures the level of confidence in performing ten basic activities of daily living (ADLs) (e.g., getting in or out of chair or bed, dressing, light housekeeping) without falling using a 10-point rating scale of confidence from 0 (no confidence) to 10 (complete confidence).⁷ The FES presented a ceiling effect among older adults with higher physical function, despite its good reliability and validity.⁹ To address this gap, another commonly used measure was established. Powell and Myers developed the Activities-Specific Balance Scale (ABC) in 1995 by including activities at a broad continuum of difficulty.⁹ Specifically, the ABC is a 16-item scale that assesses an individual's confidence to maintain balance while performing both basic ADLs and instrumental activities of daily living (IADLs) with higher levels of difficulty such as walking in the crowded mall and on icy sidewalks. Powell and Myers pointed out that the ABC might be more appropriate for more active individuals. Furthermore, the ABC uses a scale ranging from 0% (no confidence) to 100% (complete confidence), which makes it difficult to respond accurately.¹⁸

Another frequently used outcome measure related to the affective construct of FOF is the fall efficacy scale-international (FES-I) developed by Yardley et al. in 2005.¹⁴ The FES-I was developed based on the FES; however, it includes more challenging social activities. Unlike the FES which measures falls-related self-efficacy, the FES-I measures the level of concern about falling when performing physical and social activities using a 4-point Likert-type scale ranging from 1 (not at all concerned) to 4 (very concerned).

To assess both the affective construct (worry about falling) and the behavioral change (activity restriction) elements of FOF, the Survey of Activities and Fear of Falling in the Elderly (SAFE) was developed.¹⁶ The items of the SAFE contain five ADLs and IADLs, nine mobility activities and three social activities and are rated on a 4-point scale of 0 (not at all worried) to 3 (very worried). The SAFE can also identify the activities that are avoided due to worry about falling. For example, it includes questions like *"do you currently do the activity?"*, *"if you do not do the activity, do you not do it because you are worried?"*.¹⁶ Similarly, Landers and colleagues developed the fear of falling avoidance behavior

questionnaire (FFABQ) to quantify FOF-induced activity/participation avoidance based on the fear-avoidance model of pain.¹⁵ It contains items of ADLs (e.g., showering, going up and downstairs), IADLs (e.g., preparing meals, and doing housework), and social activities (e.g., recreational activities and volunteer work) and uses a 5-point Likert-type scale ranging from completely disagree to completely agree in order to rate FOF induced activity avoidance.

2.3 Epidemiology

The prevalence of FOF among community-dwelling older adults varies across epidemiological studies, ranging from 3% to 85%.¹⁹ According to a systematic review by Scheffer and colleagues, all included studies had prevalence between 21% and 85% (except one study where the prevalence of FOF among non-dizzy community-dwelling older adults was 3%).¹⁹ The prevalence of FOF among community-dwelling older adults also differs across countries with 34% in Canada,²⁰ from 29% to 60% in the USA,^{21,22} 48.2% in Israel,²³ 53.4% in Taiwan,²⁴ 57.9% in Japan,²⁵ 64.73% in Hong Kong,²⁶ 76.6% in Korea,²⁷ and 86.6% in Turkey.²⁸ The great variability of FOF prevalence could be explained by the variations in population characteristics, study settings and measurement tools.²⁹

Several studies reported the incidence of FOF. According to Rivasi et al., 18% of participants (≥ 60 years) developed FOF in a 2.1 year period.³⁰ They also found that FOF was more likely to occur in individuals who were older, frailer, had a history of falls, had worse performance in balance and physical function tests and needed a walking aid during the assessment.³⁰ In Lach's study, 22.5% of older adults over the age of 65 developed FOF after two years.³¹ Based on their study, the incidence of FOF was associated with having two or more falls, feeling unsteady, and having fair or poor health status.³¹ Murphy and colleagues' study examined the incidence of FOF among women aged 72 and older and revealed that 27% of women developed FOF at a 1-year follow-up.³²

2.4 Risk Factors and Consequences of FOF

In this section, I will first discuss the major risk factors of FOF, followed by the consequences of FOF in this section.

2.4.1 Risk Factors

FOF has a multifactorial etiology among community-dwelling older adults that includes fall history and sociodemographic, physical, psychological and environmental factors.

Fall history

Although FOF occurs in non-fallers, FOF is more prevalent among older adults who have falling experiences.^{5,23,29,33-35} Up to 92% of community-dwelling older adults who fell in the previous year experienced FOF.^{5,35} According to Frankenthal et al., FOF was about twice as likely to occur among those who had fallen in the previous year than among those who had not.²³ Furthermore, dominant evidence has indicated that fall history is a significant predictor of FOF. According to systematic reviews by Denkinger et al.'s and Scheffer et al., the significant versus insignificant association ratio between fall history and FOF-related outcomes was 26 to 19, indicating that 73% of FOF-related outcomes were significantly associated with fall history in the literature they reviewed.^{11,19} Similar findings were also reported in recent studies.^{23,28}

Sociodemographic factors

In terms of sociodemographic factors, robust evidence has shown that age and gender were the main risk factors associated with FOF. As shown in Martinez et al.'s study, older adults greater than 75 years are two times more likely to have high FOF.³⁶ Likewise, an older age (≥ 80 years) in Zijlstra et al.'s study³⁷ and (≥ 85 years) in Park et al.'s study³⁸ was independently associated with the increased level of FOF. Furthermore, the female gender was a strong predictor of FOF in many studies.^{23,27,36-43} Particularly, results from these studies showed that FOF was 1.64 to 5.55 times more likely to occur in women than in men.^{27,36} Another study examined the relationship between the female gender and FOF among older adults with and without fall history.⁴² The researchers found that, when compared with men, older female adults in the fall history group had a five-times greater likelihood of having a high FOF level. Those without a fall history had a three-times greater likelihood of having a high FOF level than men in the same category.⁴²

Evidence is less robust regarding the association between FOF and other sociodemographic factors such as ethnicity, marital status, education level, and socioeconomic status. For example, Kumar

and colleagues found that the odds of FOF were significantly increased among community-dwelling older adults who were African American, had lower household income, and had a lower educational level.⁴⁴ Similarly, low income was found to be an independent risk factor for FOF-related activity restriction and a lower-level education was identified as an independent predictor of FOF.^{38,45} Nevertheless, these factors (i.e., ethnicity, education level and socioeconomic status) were not significant determinants of FOF in other studies.^{36,39,40,46,47}

Physical function

FOF has been primarily attributed to poor physical function, specifically mobility disability, ADL and IADL impairments, reduced balance capacity and lower limb muscle strength. By systematically reviewing publications from January 2006 to October 2012, Denkinger et al. found that the use of a walking aid, walking disability, mobility disability, IADL and ADL impairments were most associated with increased FOF across all domains.¹¹ Numerous studies that were published before 2006 and after 2012 produced similar evidence. Particularly, studies have identified the impairment of IADLs and ADLs as a significant predictor of a high level of FOF.^{6,23,27,34,43,47-50} Likewise, Curcio and colleagues found that participants with a high level of mobility disability were 6.3 times more likely to develop FOF compared to participants with a low level of mobility disability.⁵¹ Kumar et al. demonstrated that the use of a walking aid, difficulty in using public transport, poorer perceived physical health, and self-reported balance problems were factors significantly increasing the odds of FOF.⁴⁴ Furthermore, FOF is also associated with balance and lower limb muscle strength. According to Hoang et al., a high level of FOF was significantly correlated with poor mobility, and balance measured by the Timed Up and Go (TUG) test, Functional Reach Test, and Tandem Gait Test.⁴⁸ Tomita et al. found that women with less muscle strength in lower extremities measured by the Five Times chair stand times were more likely to have FOF.²⁹ Similarly, Kumar et al. also found that inability to rise from a chair of knee height increased the chance of having a high level of FOF.⁴⁴

Psychological factors

A growing number of recent studies worldwide appear to confirm that depression is a significant determinant of FOF. For example, Mane and colleagues found FOF was significantly correlated to depression among older adults above 60 years in an urban area of Karnataka, India.⁵² Similarly, Hoang and colleagues found that depression was significantly and positively related to FOF in older adults.⁴⁸ Rivasi et al.'s study revealed that a higher burden of depressive symptoms at baseline were predictors for developing FOF among community-dwelling older adults.³⁰ Moreover, both depressive and anxiety symptoms were found to be associated with FOF in Liu et al.'s study.²⁶ However, findings from Denkinger et al.'s systematic review showed that there had been conflicting results for the association between FOF and anxiety.¹¹ Findings on this variable from Denkinger et al.'s study were only based on three studies. A systematic review and meta-analysis of 20 studies by Payette et al. yielded an opposite conclusion from Denkinger et al.'s systematic review regarding the relationship between anxiety and FOF.¹² Payette et al. found a significant moderate association between anxiety and FOF.¹²

Environmental factors

A few studies have identified environmental factors as predictors of FOF. The findings from Curl et al.'s study suggested that perceived accessibility and difficulties with walking in the local neighbourhood were independent predictors of FOF.⁵³ Cho et al. compared the prevalence of FOF in urban communities to that in rural communities with respect to social demographics, health status, and functional level.³⁴ They implied that FOF was more prevalent among rural residents when compared with urban residents who were from lower-income or educational backgrounds, were physical workers or unemployed, and were free of chronic medical morbidity or functionally independent.³⁴ Based on Filiatrault et al.'s study, older adults living in a smaller city or rural area were more likely to be affected by FOF than older adults living in a larger city.³⁹

Additional risk factors

While the prior outlined factors have been increasingly identified as significant predictors, there are additional risk factors that have less robust evidence to date and need further investigation. These additional factors include cognitive impairment, living status, health status and perceived general health.

Some studies found that impaired cognitive performance was associated with FOF.⁵⁴⁻⁵⁶ However, other studies did not find cognitive impairment to be associated with FOF.^{1,40,49,57} Additionally, living alone was found to be a predictor of FOF in some studies,^{39,41,55} but not in other studies.^{36,37,49,58} Finally, Lach et al. and Zijlstra et al. found that poor health status and perceived general health were associated with FOF, but few other studies had the same finding.^{37,59}

2.4.2 Consequences of FOF

Research on FOF has become increasingly important due to its adverse biopsychosocial consequences such as a decline in physical function and mental health, restriction of physical and social participation, increase in fall risks, and mortality.⁶⁰ A systematic review by Scheffer and colleagues analyzed 28 studies published between 1990 and 2006. They examined the relationship between FOF and possible health consequences among community-dwelling older adults.¹⁹ Among their reviewed studies, FOF contributed to activity restriction, a decrease in physical activity and quality of life, increased fall risks, balance and gait impairment, and depression.¹⁹

FOF contributes to activity and social participation restriction. Many studies have explored the impact of FOF-induced activity and participation restrictions on health outcomes. A recent systematic review found that FOF was an independent predictor of physical and psychological impairments, and these impairments were partially mediated by FOF-induced activity restriction.³³ Additionally, Deshpande and colleagues found that 75% of participants in their study experiencing FOF reported moderate to severe activity restriction.¹ This FOF-induced moderate and severe activity restriction was significantly associated with worsening ADL disability and decline in lower extremity performance at the three-year follow-up.¹ Finally, Auais and colleagues investigated the relationship between FOF and life-space mobility among 1841 older adults from four different countries.⁶¹ They found that FOF was strongly associated with a reduction in life-space mobility.⁶¹ Individuals' life-space mobility is determined by the specific area they negotiate on a daily basis and is indicative of their activity and social participation status; restricted life-space mobility leads to or exacerbates existing poor physical function, frailty, disability and mortality.⁶²⁻⁶⁴

FOF contributes to poor physical function. FOF is linked to poor balance, postural control, and risk of falling. Yong et al. signified that FOF was associated with adapting a “stiffening strategy” for postural control, which compromises balance performance during dynamic and highly demanding activities such as dual tasks.⁶⁵ Similarly, Holtzer and colleagues found that FOF in older adults was associated with higher and inefficient activation of the prefrontal cortex during dual-task walking.⁶⁶ Lavedan and colleagues explored whether FOF contributes to falls and found that FOF was a predictor of the incidence of falls at 25-months follow-up.⁶⁷ Moreover, FOF might predict the incidence of mobility disability and poor physical performance. For example, Auais and colleagues conducted a longitudinal study to examine the contribution of FOF on the incidence of functional disability over a 2-year period among community-dwelling older adults across four sites.⁶⁸ Their findings showed that increasing the FES-I by one point at baseline increased the risk of developing mobility disability and poor physical performance by 4% and 3% respectively, two years later.⁶⁸

FOF contributes to decreased quality of life and mental health and increased mortality. A recent systematic review found that increased FOF is a strong predictor of decreased quality of life.³³ Chang and colleagues also found that FOF was a major risk factor in predicting poor physical and mental components of health-related quality of life measured by the 36-Item Short Form Survey (SF-36).⁶⁹ Furthermore, Hajek et al.’s study showed that FOF was associated with increased depressive symptoms, lower life satisfaction and perceived autonomy.⁷⁰ Finally, according to Kim and colleagues, participants with a high level of FOF had significantly higher mortality as compared to those with a low level of FOF.⁷¹

In summary, FOF has a multifactorial etiology comprising non-modifiable and modifiable risk factors. As demonstrated in many research findings, fall history, older age, and female gender were common non-modifiable risk factors of FOF. Mobility disability, poor balance and muscle strength, depression and anxiety, and poor accessibility of the local neighborhood were the modifiable risk factors associated with a high prevalence and level of FOF.

In many cases, a mild degree of FOF can prevent older adults from engaging in dangerous physical activities,⁷² but becomes dysfunctional when it grows to the level that prevents them from doing normal physical and social activities, potentially leading to an escalating vicious cycle of activity restriction, deconditioning, and more falls.¹⁵ To break this vicious cycle, various types of interventions targeting those modifiable FOF risk factors have been investigated.⁷³⁻⁷⁶ I will provide an overview of different types of FOF interventions by reviewing existing reviews in the next section.

2.5 FOF Interventions

A total of 11 data synthesis studies (5 systematic reviews with meta-analyses, 3 systematic reviews, 1 scoping, 1 updated review and 1 meta-analysis) published between 2007 and 2020 have been identified from the current literature on FOF interventions. These studies investigated the effectiveness of broad categories of FOF interventions among community-dwelling older adults. Table 1 summarizes the main findings of these reviews.

Given the different constructs (i.e., cognitive and affective construct) and multi-dimensional modifiable risk factors (i.e., physical, psychological, and environmental factors) linked to FOF, existing FOF interventions in the literature can be categorized as exercise, psychological, environmental, and other interventions. Exercise interventions consist of different exercise types such as balance, strength, aerobic, Tai Chi and multi-component exercises (e.g., a combination of balance and strength exercise). The psychological interventions include cognitive behavioral therapy (CBT), education, and mental imagery. The environmental intervention focuses on environmental assessment and modification. The other interventions include wearing hip protectors, fall risk assessment, and multifactorial interventions (e.g., a combination of physical and psychological intervention).

Table 1: Effects of types of FOF interventions

First author of the	Type of the review (# of included studies)	Type(s) of interventions	Types of studies included in the review	Main findings
---------------------	--	--------------------------	---	---------------

review (year)				
Reviews on all types of FOF interventions				
Zilstra (2007) ⁷⁷	Systematic review (n=19)	Exercise, Fall- related multifactorial intervention, CBT	RCTs	Eleven trials reported a statistically significant reduction of FOF, and they were fall-related multifactorial programs (n=5), community-based Tai Chi programs (n=3), home-based multi- component exercise programs (n=2), and a hip protector program (n=1)
Bula (2011) ⁷⁸	Updated systematic review (n=46)	Exercise, CBT, Education, Environmental adaptation, Nutritional intervention, Vision correction, Hip protector	RCTs	Exercises containing strengthening and balance components and Tai Chi were the most frequently used interventions and showed the most consistent positive effect on balance confidence.
Whipple (2018) ⁷⁹	Scoping review (n=26)	Exercise, CBT, Guided relaxation, Virtual reality trainer, Fall- related multifactorial intervention	RCTs	Exercise interventions such as walking, water-based training, and Tai Chi aimed at improving strength, balance, agility and flexibility alone or in combination and psychological interventions such as CBT, guided relaxation and virtual reality training were effective in reducing FOF.
Kruisbrink (2020) ⁷⁴	Systematic review (n=62) and meta- analysis(n=5 0)	Exercise, CBT, Assess-based home care and modification, Education, Nutritional	RCTs	The pooled estimate of SMD of fifty study arms was -0.36 (95%CI: -0.48; - 0.24), indicating that interventions resulted in a significant small-to- moderate reduction in FOF

		supplementation, Mental imagery, A referral protocol for emergency ambulance visits		
Reviews on fall prevention programs				
Sjosten (2008) ⁷⁶	Systematic review(n=24)	Fall prevention programs	RCTs	The fall prevention interventions appear to be effective in reducing FOF since around 70% of trials yielded significant results in FOF reduction.
Yoshikawa (2020) ¹³	Systematic review (n=17) and meta-analysis (n=13)	Fall prevention program (AMOB/ALL)	RCTs, Quasi-experimental studies	The effect size of AMOB/ALL fall prevention program on FOF measured by affective construct was an SMD of -0.29 (9 studies, CI: -0.4, -0.19) and on FOF measured by cognitive construct was SMD of 0.51 (10 studies, CI: 0.42, 0.60), meaning that AMOB/ALL fall prevention program has a small-to-moderate effect in managing FOF.
Reviews on CBT interventions				
Liu (2018) ⁸⁰	Systematic review (n=6) and meta-analysis (n=5)	CBT	RCTs	CBT interventions have significant immediate (SMD=0.25, 95% CI 0.09, 0.41) and long-term (≤ 12 month) effects (SMD=0.37, 95% CI 0.21, 0.53) on reducing FOF
Chua (2019) ⁷⁵	Systematic review (n=15) and meta-	CBT-based multifactorial interventions	RCTs	The pooled immediate CBT-based multifactorial intervention effect was an SMD of -0.28 (95% CI -0.35, -0.21), the pooled short-term (≤ 6 month) intervention effect was an SMD of -0.32 (95% CI -

	analysis (n=15)			0.49, -0.15) and the pooled long-term (>6month) intervention effect was an SMD of -0.30 (95% CI -0.45, -0.14).
Reviews on exercise interventions				
Harling (2008) ⁸¹	Systematic review (n=7)	Exercise (Tai Chi)	RCTs	Of seven included RCTs, five trials with high methodological quality demonstrated a significant effect of Tai Chi exercise in FOF reduction.
Logghe (2010) ⁸²	Meta- analysis (n=21)	Exercise (Tai Chi)	RCTs	The pooled estimate of SMD of three trials on FOF reduction was an SMD of 0.37.
Kumar (2016) ⁷³	Systematic review (n=30) and meta- analysis (n=25)	Exercise (all types)	RCTs, Quasi- experiment al studies	The pooled estimate of SMD of 24 trials on FOF reduction was an SMD of 0.37.

Note. RCTs: Randomized Controlled Trials; CBT: Cognitive Behavioral Therapy; SMD: Standardized Mean Difference; CI: Confidence Interval; AMOB/ALL: A Matter of Balance Volunteer Lay Leader; #/n: numbers.

Among identified reviews, four studies reviewed all types of FOF interventions in community-dwelling older adults.^{74,77-79} Findings from Zilstra and colleagues' systematic review revealed that fall-related multifactorial programs, community-based Tai Chi programs, home-based multi-component exercise programs, and a hip protector program were effective in reducing FOF among community-dwelling older adults.⁷⁷ According to Bula et al.'s review, programs containing strengthening and balance exercises or Tai Chi were the most frequently used interventions and showed the most consistent positive effect on balance confidence.⁷⁸ In Whipple et al.'s scoping review, no clear consensus has been established regarding the best type of FOF intervention. However, the authors noted that interventions comprised of exercise and CBT are consistently superior to standard care.⁷⁹ A recent systematic review and meta-analysis of RCTs aimed to explore the relationship between effective FOF interventions for community-dwelling older adults and overarching characteristics of FOF interventions such as type of

supervisor, delivery method, and settings.⁷⁴ The meta-regression analyses in this review showed that holistic exercises (i.e., Tai Chi, yoga, vinyasa, or pilates), a Tai Chi program supervised by an instructor and interventions delivered in a community setting were characteristics that were associated with a significant effect of interventions on FOF reduction.⁷⁴

Two studies reviewed the effectiveness of fall prevention programs on reducing FOF.^{13,76} Fall prevention programs include both single-factorial and multifactorial fall prevention programs targeting one or multiple risk factors of falls such as poor balance, impaired muscle strength, FOF, side-effects of medication and environmental hazards. Sjostrom and colleagues found that fall prevention interventions appear to be effective in reducing FOF since around 70% of trials yielded significant results in FOF reduction.⁷⁶ In Yoshikawa et al.'s systematic review and meta-analysis, a community-based fall prevention program called A Matter of Balance Volunteer Lay Leader (AMOB/ALL) model had a small-to-moderate effect size in reducing FOF.¹³ However, I should note that most of the included studies in this review used a quasi-experimental design. Potential selection bias, maturation bias and historical bias might limit the study's ability to identify the true program effect.

Two studies reviewed the effectiveness of CBT in reducing FOF.^{75,80} CBT as a psychotherapeutic intervention to manage FOF through modifying individuals' thoughts, and behaviors has increasingly gained attention in the past decade. In Liu et al.'s systematic review and meta-analysis, CBT interventions have significant immediate and long-term (≤ 12 months) effects on reducing FOF.⁸⁰ They also found that individual-based CBT interventions were more effective than group-based interventions in FOF reduction.⁸⁰ Chua and colleagues looked at the effectiveness of CBT-based multicomponent interventions on FOF reduction among community-dwelling older adults at risk of falling.⁷⁵ The results implied that interventions involving CBT as part of a biopsychosocial intervention program have positive short- and long-term effects on reducing FOF among community-dwelling older adults with fall risks.⁷⁵

Three studies reviewed the effectiveness of exercise interventions in reducing FOF.^{81,82} Exercise of all types has been the most common intervention to reduce FOF due to its benefits on improving balance, muscle strength, and stamina. Harling et al., in 2008, systematically reviewed RCTs that used

Tai Chi as interventions to reduce FOF among older adults 60 years and older, living in the community or in institutions.⁸¹ Of seven included RCTs, five trials with high methodological quality demonstrated a significant effect of Tai Chi exercise on FOF reduction.⁸¹ Among these five trials, four trials used Tai Chi exercise alone as intervention and one trial incorporated Tai Chi with resistance and functional-balance training.⁸¹ Though they concluded that the Yang style Tai Chi appears to offer the greatest benefits, there was insufficient information regarding how Tai Chi exercise programs have been implemented in the research and what were the frequency, duration, and intensity of Tai Chi exercises. Therefore, we should interpret the findings with caution since different implementation methods and doses may alter the effectiveness of Tai Chi interventions.

A meta-analysis was performed by Logghe et al. in 2010 to evaluate the effectiveness of Tai Chi as a single-component intervention on FOF, fall rate and balance in healthy adults aged 50 years or older.⁸² They found that compared with non-exercise controls, Tai Chi participants showed a significant reduction in FOF.⁸² Nevertheless, due to the limited number of analyzed trials (3 trials analyzed), evidence is insufficient to conclude that Tai Chi effectively reduces FOF in people over the age of 50.

In Kumar's Cochrane systematic review and meta-analysis on the effect of exercise intervention in reducing FOF in community-dwelling older adults (≥ 65 years), 30 trials published up to 2013 were included in the qualitative synthesis and 25 in the quantitative synthesis.⁷³ Among a total of 36 interventions in 30 trials, most of the interventions were in respect to gait, balance, coordination, and functional training (53%), were supervised (75%), delivered in group settings (56%), lasted ≤ 12 weeks (61%) and had a frequency of 1 to 3 times per week (89%).⁷³ Findings from the meta-analysis demonstrated a small-to-moderate effect size (SMD=0.37; 95% CI= 0.18 to 0.56) of exercise interventions on FOF reduction in community-dwelling older adults immediately following the exercise interventions.⁷³ However, most of their included trials were appraised to have a high risk of bias (i.e., performance and detection bias). The variables such as the intensity and types of exercise that may impact the effect of exercise interventions are yet to be clarified. Many important trials in this field have been published after 2013, necessitating an updated and more comprehensive review.

To conclude, the current evidence drawn from existing reviews shows that exercise interventions such as Tai Chi and multi-component exercises or exercises incorporated with CBT as a multifactorial intervention can effectively reduce FOF among community-dwelling older adults. Despite the essential role of exercise interventions in reducing FOF among community-dwelling older adults, no reviews have taken the essential step to report the measures of exercise prescription. Reporting the measures of exercise prescription according to the principles of exercise training and the FITT exercise prescription framework is valuable for readers with different backgrounds in order to critically appraise the actual effectiveness of different exercise interventions in reducing FOF. Such reporting also facilitates the real-world application of evidence and provides policymakers with strategies for developing FOF exercise program guidelines. Therefore, this thesis aims to examine the extent to which FOF exercise interventions followed the principles of exercise training and reported FITT components, to pool the effect size of exercise interventions in reducing FOF in community-dwelling older adults, and to explore variables that might impact the effect size of included exercise interventions.

2.6 References

1. Deshpande N, Metter EJ, Bandinelli S, Lauretani F, Windham BG, Ferrucci L. Psychological, physical and sensory correlates of fear of falling and consequent activity restriction in the elderly: the InCHIANTI Study. *American Journal of Physical Medicine & Rehabilitation/Association of Academic Physiatrists*. 2008;87(5):354.
2. Marks I, Bebbington P. Space phobia: syndrome or agoraphobic variant? *Br Med J*. 1976;2(6031):345-347.
3. Bhala RP, O'Donnell J, Thoppil E. Ptophobia: phobic fear of falling and its clinical management. *Physical Therapy*. 1982;62(2):187-190.
4. Murphy J, Isaacs B. The post-fall syndrome. *Gerontology*. 1982;28(4):265-270.
5. Jørstad EC, Hauer K, Becker C, Lamb SE, Group obotP. Measuring the psychological outcomes of falling: a systematic review. *Journal of the American Geriatrics Society*. 2005;53(3):501-510.
6. Suzuki M, Ohyama N, Yamada K, Kanamori M. The relationship between fear of falling, activities of daily living and quality of life among elderly individuals. *Nursing & Health Sciences*. 2002;4(4):155-161.
7. Tinetti ME, Richman D, Powell L. Falls efficacy as a measure of fear of falling. *Journal of Gerontology*. 1990;45(6):P239-P243.
8. Tinetti ME, Powell L. Fear of falling and low self-efficacy: a cause of dependence in elderly persons. *Journal of Gerontology*. 1993.
9. Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) scale. *The Journals of Gerontology: Series A*. 1995;50A(1):M28-M34.
10. Bandura A. Self-efficacy determinants of anticipated fears and calamities. *J Pers Soc Psychol*. 1983;45:464
11. Denking MD, Lukas A, Nikolaus T, Hauer K. Factors associated with fear of falling and associated activity restriction in community-dwelling older adults: a systematic review. *The American Journal of Geriatric Psychiatry*. 2015;23(1):72-86.
12. Payette M-C, Belanger C, Léveillé V, Grenier S. Fall-related psychological concerns and anxiety among community-dwelling older adults: systematic review and meta-analysis. *PLoS one*. 2016;11(4):e0152848.
13. Yoshikawa A, Ramirez G, Smith ML, Lee S, Ory MG. Systematic review and meta-analysis of fear of falling and fall-related efficacy in a widely disseminated community-based fall prevention program. *Archives of Gerontology and Geriatrics*. 2020;91:104235.
14. Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing*. 2005;34(6):614-619.
15. Landers MR, Durand C, Powell DS, Dibble LE, Young DL. Development of a scale to assess avoidance behavior due to a fear of falling: the Fear of Falling Avoidance Behavior Questionnaire. *Phys Ther*. 2011;91(8):1253-1265.
16. Lachman ME, Howland J, Tennstedt S, Jette A, Assmann S, Peterson EW. Fear of Falling and Activity Restriction: The Survey of Activities and Fear of Falling in the Elderly (SAFE). *The Journals of Gerontology: Series B*. 1998;53B(1):P43-P50.
17. Scheffer AC, Schuurmans MJ, VanDijk N, Van Der Hooft T, De Rooij SE. Reliability and validity of the visual analogue scale for fear of falling in older persons. *Journal of the American Geriatrics Society*. 2010;58(11):2228-2230.
18. Greenberg SA. Analysis of measurement tools of fear of falling for high-risk, community-dwelling older adults. *Clinical Nursing Research*. 2012;21(1):113-130.

19. Scheffer AC, Schuurmans MJ, van Dijk N, van der Hooft T, de Rooij SE. Fear of falling: measurement strategy, prevalence, risk factors and consequences among older persons. *Age and Ageing*. 2008;37(1):19-24.
20. Pearson C, St-Arnaud J, Geran L. Understanding seniors' risk of falling and their perception of risk. Ottawa: Statistics Canada; 2017.
21. Uemura K, Yamada M, Nagai K, Tanaka B, Mori S, Ichihashi N. Fear of falling is associated with prolonged anticipatory postural adjustment during gait initiation under dual-task conditions in older adults. *Gait & Posture*. 2012;35(2):282-286.
22. Rahman M. Prevalence and risk factors of fear of falling among elderly: a review. *Medical Journal of Clinical Trials & Case Studies*. 2018;2.
23. Frankenthal D, Saban M, Karolinsky D, et al. Falls and fear of falling among Israeli community-dwelling older people: a cross-sectional national survey. *Israel Journal of Health Policy Research*. 2021;10(1):1-8.
24. Chang H-T, Chen H-C, Chou P. Factors associated with fear of falling among community-dwelling older adults in the Shih-Pai study in Taiwan. *PLoS One*. 2016;11(3):e0150612.
25. Sakurai R, Fujiwara Y, Yasunaga M, et al. Association of confidence in motor function and fear of falling with physical ability in community-dwelling older people. *Nihon Ronen Igakkai Zasshi Japanese Journal of Geriatrics*. 2013;50(3):369-376.
26. Liu JYW. Fear of falling in robust community-dwelling older people: results of a cross-sectional study. *Journal of Clinical Nursing*. 2015;24(3-4):393-405.
27. Kim S, So W-Y. Prevalence and correlates of fear of falling in Korean community-dwelling elderly subjects. *Experimental Gerontology*. 2013;48(11):1323-1328.
28. Simsek H, Erkoyun E, Akoz A, Ergor A, Ucku R. Falls, fear of falling and related factors in community-dwelling individuals aged 80 and over in Turkey. *Australasian Journal on Ageing*. 2020;39(1):e16-e23.
29. Tomita Y, Arima K, Tsujimoto R, et al. Prevalence of fear of falling and associated factors among Japanese community-dwelling older adults. *Medicine (Baltimore)*. 2018;97(4):e9721-e9721.
30. Rivasi G, Kenny RA, Ungar A, Romero-Ortuno R. Predictors of incident fear of falling in community-dwelling older adults. *Journal of the American Medical Directors Association*. 2020;21(5):615-620.
31. Lach HW. Incidence and risk factors for developing fear of falling in older adults. *Public Health Nurs*. 2005;22(1):45-52.
32. Murphy SL, Dubin JA, Gill TM. The Development of fear of falling among community-living older women: predisposing factors and subsequent fall events. *The Journals of Gerontology: Series A*. 2003;58(10):M943-M947.
33. Schoene D, Heller C, Aung YN, Sieber CC, Kemmler W, Freiburger E. A systematic review on the influence of fear of falling on quality of life in older people: is there a role for falls? *Clinical Interventions in Aging*. 2019;14:701.
34. Cho H, Seol SJ, Do Hyun Yoon MJK, Choi BY, Kim T. Disparity in the fear of falling between urban and rural residents in relation with socio-economic variables, health issues, and functional independency. *Annals of Rehabilitation Medicine*. 2013;37(6):848.
35. Evitt CP, Quigley PA. Fear of falling in older adults: a guide to its prevalence, risk factors, and consequences. *Rehabilitation Nursing*. 2004;29(6):207.
36. Martínez IP, Bravo BN, Pretel FA, Muñoz J, Molina R, Hidalgo J. Fear of falling in elderly community-dwelling individuals. *Gaceta Sanitaria*. 2010;24(6):453-459.
37. Zijlstra G, Van Haastregt J, Van Eijk JTM, van Rossum E, Stalenhoef PA, Kempen GI. Prevalence and correlates of fear of falling, and associated avoidance of activity in the

- general population of community-living older people. *Age and Ageing*. 2007;36(3):304-309.
38. Park J-I, Yang J-C, Chung S. Risk factors associated with the fear of falling in community-living elderly people in Korea: role of psychological factors. *Psychiatry Investigation*. 2017;14(6):894.
 39. Filiatrault J, Desrosiers J, Trottier L. An exploratory study of individual and environmental correlates of fear of falling among community-dwelling seniors. *Journal of Aging and Health*. 2009;21(6):881-894.
 40. Oh-Park M, Xue X, Holtzer R, Verghese J. Transient versus persistent fear of falling in community-dwelling older adults: incidence and risk factors. *Journal of the American Geriatrics Society*. 2011;59(7):1225-1231.
 41. da Costa EM, Pepersack T, Godin I, Bantuelle M, Petit B, Levêque A. Fear of falling and associated activity restriction in older people. results of a cross-sectional study conducted in a Belgian town. *Archives of Public Health*. 2012;70(1):1-8.
 42. Lee S, Oh E, Hong G-RS. Comparison of factors associated with fear of falling between older adults with and without a fall history. *International Journal of Environmental Research and Public Health*. 2018;15(5):982.
 43. Curcio C-L, Gomez F, Reyes-Ortiz CA. Activity restriction related to fear of falling among older people in the Colombian Andes mountains: are functional or psychosocial risk factors more important? *Journal of Aging and Health*. 2009;21(3):460-479.
 44. Kumar A, Carpenter H, Morris R, Iliffe S, Kendrick D. Which factors are associated with fear of falling in community-dwelling older people? *Age and Ageing*. 2014;43(1):76-84.
 45. Curcio C-L, Wu YY, Vafaei A, et al. A regression tree for identifying risk factors for fear of falling: the International Mobility in Aging Study (IMIAS). *The Journals of Gerontology: Series A*. 2020;75(1):181-188.
 46. Ramulu PY, Van Landingham SW, Massof RW, Chan ES, Ferrucci L, Friedman DS. Fear of falling and visual field loss from glaucoma. *Ophthalmology*. 2012;119(7):1352-1358.
 47. Shin KR, Kang Y, Kim MY, et al. Impact of depression and activities of daily living on the fear of falling in Korean community-dwelling elderly. *Nursing & health sciences*. 2010;12(4):493-498.
 48. Hoang OTT, Jullamate P, Piphatvanitcha N, Rosenberg E. Factors related to fear of falling among community-dwelling older adults. *Journal of Clinical Nursing*. 2017;26(1-2):68-76.
 49. Kempen GI, van Haastregt JC, McKee KJ, Delbaere K, Zijlstra GR. Socio-demographic, health-related and psychosocial correlates of fear of falling and avoidance of activity in community-living older persons who avoid activity due to fear of falling. *BMC Public Health*. 2009;9(1):1-7.
 50. Patil R, Uusi-Rasi K, Kannus P, Karinkanta S, Sievänen H. Concern about falling in older women with a history of falls: associations with health, functional ability, physical activity and quality of life. *Gerontology*. 2014;60(1):22-30.
 51. Curcio C, Wu Y, Vafaei A, et al. A regression tree for identifying risk facots for fear of falling: the International Mobility In Aging Study (IMIAS). *Innovation in Aging*. 2018;2:891-891.
 52. Mane AB, Sanjana T, Patil PR, Srinivas T. Prevalence and correlates of fear of falling among elderly population in urban area of Karnataka, India. *Journal of Mid-life Health*. 2014;5(3):150.
 53. Curl A, Fitt H, Tomintz M. Experiences of the built environment, falls and fear of falling outdoors among older adults: an exploratory study and future directions. *International Journal of Environmental Research and Public Health*. 2020;17(4):1224.

54. Fletcher PC, Guthrie DM, Berg K, Hirdes JP. Risk factors for restriction in activity associated with fear of falling among seniors within the community. *Journal of Patient Safety*. 2010;6(3):187-191.
55. Austin N, Devine A, Dick I, Prince R, Bruce D. Fear of falling in older women: a longitudinal study of incidence, persistence, and predictors. *Journal of the American Geriatrics Society*. 2007;55(10):1598-1603.
56. Yardley L, Smith H. A prospective study of the relationship between feared consequences of falling and avoidance of activity in community-living older people. *The Gerontologist*. 2002;42(1):17-23.
57. Rossat A, Beauchet O, Nitenberg C, Annweiler C, Fantino B. Risk factors for fear of falling: A cross-sectional population-based study. *Journal of the American Geriatrics Society*. 2009;57(7):1304-1306.
58. van Haastregt JC, Zijlstra GR, van Rossum E, van Eijk JTM, Kempen GI. Feelings of anxiety and symptoms of depression in community-living older persons who avoid activity for fear of falling. *The American Journal of Geriatric Psychiatry*. 2008;16(3):186-193.
59. Lach HW. Incidence and risk factors for developing fear of falling in older adults. *Public Health Nursing*. 2005;22(1):45-52.
60. Trombetti A, Reid K, Hars M, et al. Age-associated declines in muscle mass, strength, power, and physical performance: impact on fear of falling and quality of life. *Osteoporosis International*. 2016;27(2):463-471.
61. Auais M, Alvarado B, Guerra R, et al. Fear of falling and its association with life-space mobility of older adults: a cross-sectional analysis using data from five international sites. *Age and Ageing*. 2017;46(3):459-465.
62. Boyle PA, Buchman AS, Barnes LL, James BD, Bennett DA. Association between life space and risk of mortality in advanced age. *Journal of the American Geriatrics Society*. 2010;58(10):1925-1930.
63. Xue Q-L, Fried LP, Glass TA, Laffan A, Chaves PH. Life-space constriction, development of frailty, and the competing risk of mortality: the Women's Health And Aging Study I. *American Journal of Epidemiology*. 2008;167(2):240-248.
64. James BD, Boyle PA, Buchman AS, Barnes LL, Bennett DA. Life space and risk of Alzheimer disease, mild cognitive impairment, and cognitive decline in old age. *The American Journal of Geriatric Psychiatry*. 2011;19(11):961-969.
65. Young WR, Williams AM. How fear of falling can increase fall-risk in older adults: applying psychological theory to practical observations. *Gait & Posture*. 2015;41(1):7-12.
66. Holtzer R, Kraut R, Izzetoglu M, Ye K. The effect of fear of falling on prefrontal cortex activation and efficiency during walking in older adults. *GeroScience*. 2019;41(1):89-100.
67. Lavedán A, Viladrosa M, Jürschik P, et al. Fear of falling in community-dwelling older adults: A cause of falls, a consequence, or both? *PLoS One*. 2018;13(3):e0194967.
68. Auais M, French S, Alvarado B, Pirkle C, Belanger E, Guralnik J. Fear of falling predicts incidence of functional disability 2 years later: a perspective from an international cohort study. *The Journals of Gerontology: Series A*. 2017;73(9):1212-1215.
69. Chang N-T, Chi L-Y, Yang N-P, Chou P. The impact of falls and fear of falling on health-related quality of life in Taiwanese elderly. *Journal of Community Health Nursing*. 2010;27(2):84-95.
70. Hajek A, König HH. What are the psychosocial consequences when fear of falling starts or ends? Evidence from an asymmetric fixed effects analysis based on longitudinal data

- from the general population. *International Journal of Geriatric Psychiatry*. 2020;35(9):1028-1035.
71. Kim J-H, Bae SM. Association between Fear of Falling (FOF) and all-cause mortality. *Archives of Gerontology and Geriatrics*. 2020;88:104017.
 72. WHO. WHO global report on falls prevention in older age. Geneva, Switzerland: World Health Organization; 2008.
 73. Kumar A, Delbaere K, Zijlstra G, et al. Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and Ageing*. 2016;45(3):345-352.
 74. Kruisbrink M, Delbaere K, Kempen GI, et al. Intervention characteristics associated with a reduction in fear of falling among community-dwelling older people: a systematic review and meta-analysis of randomized controlled trials. *The Gerontologist*. 2020.
 75. Chua CHM, Jiang Y, Lim DS, Wu VX, Wang W. Effectiveness of cognitive behaviour therapy-based multicomponent interventions on fear of falling among community-dwelling older adults: A systematic review and meta-analysis. *Journal of Advanced Nursing*. 2019;75(12):3299-3315.
 76. Sjösten N, Vaapio S, Kivelä S-L. The effects of fall prevention trials on depressive symptoms and fear of falling among the aged: a systematic review. *Aging and Mental Health*. 2008;12(1):30-46.
 77. Zijlstra GR, Van Haastregt JC, Van Rossum E, Van Eijk JTM, Yardley L, Kempen GI. Interventions to reduce fear of falling in community-living older people: a systematic review. *Journal of the American Geriatrics Society*. 2007;55(4):603-615.
 78. Büla CJ, Monod S, Hoskovec C, Rochat S. Interventions aiming at balance confidence improvement in older adults: an updated review. *Gerontology*. 2011;57(3):276-286.
 79. Whipple MO, Hamel AV, Talley KM. Fear of falling among community-dwelling older adults: A scoping review to identify effective evidence-based interventions. *Geriatric Nursing*. 2018;39(2):170-177.
 80. Liu T-W, Ng GY, Chung RC, Ng SS. Cognitive behavioural therapy for fear of falling and balance among older people: a systematic review and meta-analysis. *Age and Ageing*. 2018;47(4):520-527.
 81. Harling A, Simpson JP. A systematic review to determine the effectiveness of Tai Chi in reducing falls and fear of falling in older adults. *Physical Therapy Reviews*. 2008;13(4):237-248.
 82. Logghe IH, Verhagen AP, Rademaker AC, et al. The effects of Tai Chi on fall prevention, fear of falling and balance in older people: a meta-analysis. *Preventive Medicine*. 2010;51(3-4):222-227.

Chapter 3

Methods

3.1 Overview

A systematic review synthesizes results and summarizes empirical evidence from all available studies in a particular area. It involves a comprehensive plan, detailed search strategy and rigorous data selection process that is derived a priori to the study.¹ A meta-analysis in medical research often uses statistical approaches, integrating data from available studies into a single quantitative estimate to assess the strength of the evidence presented on a type of intervention or treatment.² A rigorous systematic review and meta-analysis are considered the highest level and most trustworthy source of evidence in the evidence-based medical literature when assessing interventions.^{1,3}

The present thesis study leveraged a systematic review methodology in order to describe the FOF exercise interventions with respect to the measures of exercise prescription and to investigate the extent to which these FOF exercise interventions in existing RCTs adhered to the principles of exercise training and reported FITT components. A meta-analysis technique was then used to examine the magnitude of the effect of FOF exercise interventions in reducing FOF among community-dwelling older adults and to explore the impact of potential variables regarding the measures of exercise prescription on the effect size of exercise interventions on FOF reduction. The systematic review was conducted with guidance from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)⁴ and AMSTAR2 checklists (Appendix G and H).⁵ The Cochrane Handbook for Systematic Reviews of Interventions was followed for conducting meta-analysis.⁶

The following sections provide a detailed description of methods that were used in conducting this systematic review and the meta-analysis, including the development of search strategies, identification and selection of studies, data extraction and quality assessment, and data synthesis and analysis.

3.2 Data Sources and Search Strategy

The search strategy was developed and performed with the help of a health science librarian using MEDLINE, Embase, PsycINFO, and CINAHL databases from the inception of each database until December 31, 2019. An AutoAlert was set up for each database for a weekly update, and all studies received before the data extraction phase (July 1, 2020) were also examined for eligibility. To supplement the electronic searching, reference lists of relevant systematic reviews were examined manually. Both medical subject headings (MeSH) and free text words were used as search terms according to the recommendations of each database. A detailed search strategy for each database can be found in appendices A to D. No language or publication date restrictions were implemented in the search process.

3.3 Study Selection

Two reviewers (C.F. and T.A.) independently screened and assessed the relevant literature based on the inclusion and exclusion criteria. Disagreements were resolved through discussion between the two reviewers. A third reviewer (M.A.) was consulted for unresolved disagreements to make the final decisions. The inclusion and exclusion criteria are as follows:

Study design. Only Randomized Controlled Trials (RCTs) were included in this systematic review. Quasi-randomization studies were excluded. In rehabilitation research, randomized controlled trials (RCTs) are the gold standard for investigating the causal relationship between exercise interventions and their effects. The superiority of RCT design lies in its ability to minimize confounding impacts of other factors that might misrepresent the effect of

interventions.⁷ It has been recognized that a systematic review of RCTs can provide the best evidence on the effectiveness of therapeutic interventions.⁸

Participants. The participants in included trials were community-dwelling older adults who were at least 65 years old. Trials that targeted specific clinical populations such as people with stroke, Parkinson's disease, dementia, or living dependently in any institutions were excluded from our study. The inclusion of articles focused on specific populations would have jeopardized the external validity of the results (i.e., reduced the applicability of findings to the general population).

Intervention. Trials in which exercise of any type was used as either the main intervention or as a secondary intervention were included in this study.

Comparator/control. RCTs with any type of the comparison group(s) (e.g., usual care, exercise, cognitive therapy) were included in the qualitative review.

Outcome measures. Included studies were required to use at least one FOF-related outcome measure, including a single-item question on the FOF, FOF-related visual analog scale,⁹ Falls Efficacy Scale (FES),¹⁰ FES-International (FES-I),¹¹ Short FES-I,¹² Activities-Specific Balance Confidence Scale (ABC),¹³ Survey of Activities and Fear of Falling in the Elderly (SAFE),¹⁴ Geriatric Fear of Falling Measure (GFFM),¹⁵ Fear of Falling Questionnaire (FFQ),¹⁶ and a measure of balance confidence (CONFbal).¹⁷

The additional inclusion criterion for the meta-analysis. In the meta-analysis, RCTs directly comparing at least one exercise arm with an inactive control arm (e.g., usual care, education class, or low-intensity exercise program that is not designed to modify the risk of falling or FOF) were included. Studies that compared two arms with active exercise were excluded from the meta-analysis.

3.4 Data Extraction and Quality Assessment

Purpose-designed data extraction sheets were created based on several previously published systematic reviews¹⁸⁻²⁰. The topic-specific information included in the data extraction sheets was determined by consensus among three reviewers (C.F., T.A., and M.A.). A pilot review of three articles was conducted independently by two reviewers (C.F. and T.A.) using the initial data extraction sheets, and modifications were made to create the final version of the data extraction tool.

Rating the reporting of principles of exercise training (Table. 2). The following operational definitions were used: **1) specificity:** interventions targeted specific body systems or body parts, **2) progression:** the dose (FITT) of exercise progressed over time, **3) overload:** exercise dose was prescribed individually in a way that challenges participants beyond their baseline levels of performance **4) initial value:** the magnitude of intervention-induced changes were compared between participants with low baseline values and participants with high baseline values, **5) reversibility:** there was at least one follow-up assessment after the intervention was completed to evaluate the long-term effect of exercise intervention, **6) diminishing return:** there was at least one mid-intervention assessment and the magnitude of intervention-induced changes between pre, mid and post-intervention assessments within the group were compared.

Rating the reporting of FITT components and adherence (Table. 2). For each trial, reviewers answered the following questions: did the author clearly describe the **1) frequency:** how often (e.g., times per week) were the participants instructed to perform the exercise? **2) intensity:** at what intensity did participants exercise? **3) time:** how long was each exercise session (e.g., minutes as well as repetitions and sets)? and **4) type:** what kind of exercises were prescribed (e.g., balance, resistance exercises)? Adherence to exercise interventions was defined as the percentage or number of the total exercise sessions attended.²¹

If each exercise principle, FITT components, and adherence were reported in the trials, “y” (for “yes”) was marked; if not, then “n” (for “not reported”) was indicated, and “Unclear” was marked when they were mentioned but not clearly described.

Table 2: Rating the reporting of principles of exercise training, FITT components and adherence

Principles	Rating criteria
Specificity	The prescribed exercises have to align with the participant’s specific needs and desired outcomes.
Progression	A gradual and systematic increase of the exercise dose over time is required to cause sustainable physiological adaptation.
Overload	The given exercise dose is greater than the dosage that the individual has adapted to.
Initial value	Participants with lower initial values have more potential to improve than participants with higher initial values.
Reversibility	The beneficial effect of exercise training will gradually decrease once the training ceases, and the downward trend can be reversed once training is resumed.
Diminishing return	The magnitude of exercise-caused improvements will decelerate when participants reach a relatively high fitness level.
Frequency	How often exercise is performed.
Intensity	The magnitude of effort required to perform the exercise.
Time	The duration of exercise in each training session.
Type	Exercise types included, e.g., resistance, endurance, aerobic, balance, and flexibility training.
Adherence	The percentage or number of the total exercise sessions attended

Rating the methodological quality of RCTs. The Physiotherapy Evidence Database (PEDro) scale was applied to assess the methodological quality of each of the RCTs included in the review.²² The PEDro scale is comprised of 11 yes-or-no questions and has been shown to be valid and reliable. One point was given to each criterion satisfied (except the first one, which examines the external validity) for a total of 10 points. The cutoff scores for the PEDro Scale (a score of 9 or 10 = “excellent,” scores of 6 to 8 = “good,” a score of 4 or 5 = “fair,” and a score of <4 = “poor”) were used to define the quality of included RCTs. In studies in which the relevant criteria were not explicitly reported, the corresponding authors of relevant studies were consulted for clarifications.

All rating scales for included RCTs were rated independently by two reviewers (C.F. and T.A.); when discrepancies arose, they were solved by a discussion between C.F. and T.A. and arbitration by a third reviewer (M.A.).

3.5 Data Synthesis and Analysis

For qualitative data, the extracted data were narratively synthesized.²³ The number and percentage of the studies which reported the principles of exercise training and FITT components were calculated. The inter-rater agreement of each rating scale between the two reviewers (C.F. and T.A.) before the discussion was calculated using Cohen’s kappa coefficient (Cohen κ). The level of reliability of the κ values was evaluated on the basis of the classification of Landis and Koch (≥ 0.81 = “almost perfect,” 0.61 to 0.81 = “substantial,” 0.41 to 0.6 = “moderate,” 0.21 to 0.4 = “fair,” and 0 to 0.2 = “poor”).²⁴

As recommended by the Cochrane Handbook, post-intervention values were entered into Review Manager to estimate the Standardized Mean Difference (SMD) or Hedges g with 95% CIs for each study with continuous data.²⁵ To allow for the variability across studies, a random effect model was applied. In trials with more than one exercise intervention arm, we combined interventions to create a single pairwise comparison according to the recommendations by Higgins et al.²⁶ Heterogeneity of trials was assessed with the χ^2 test and I^2 statistics. The I^2 represents the percentage of overall variation across studies that is

caused by heterogeneity rather than by chance.²⁶ The I^2 is calculated by the following statistic where Q is the chi-squared statistic and df is its degree of freedom.²⁶

$$I^2 = \left(\frac{Q - df}{Q} \right) \times 100\%$$

In terms of missing data, the first authors of the studies were contacted. If missing data were not obtained from the first author of any study, available data were used to calculate the missing data and complete the analysis if possible. If medians and ranges of the outcome were the only available data, the sample means and SDs were estimated following the method of Hozo et al.²⁷

In most trials, higher scores of FOF measures were indicative of higher FOF. In the few trials in which higher scores of FOF were indicative of lower FOF because of the FOF measure used, the scores were multiplied by -1 to ensure consistency in the interpretation of outcomes before entering data into the meta-analysis.^{6,28}

A series of subgroup analyses were conducted according to FOF outcome measures, types of exercise, duration of interventions in weeks and whether a FOF measure was a primary or secondary outcome. In subgroup analysis, if the studies had multiple intervention arms (e.g., ≥ 2 exercise intervention arms with one inactive control arm), each exercise intervention arm was compared separately with the control.

Sensitivity analyses were conducted to examine the impact of trials with a small sample size ($N < 100$ at randomization), and a high risk of bias (PEDro Scale score of < 6) on effect sizes. Moreover, although post-intervention values were used to estimate the intervention effects in this study, the use of change-from-baseline values is another common approach to produce effect estimates of the mean difference. According to Fu and Haley, estimating the effect size using the post-intervention values versus the change-from-baseline values may lead to discrepancies in conclusions.²⁹ Therefore, to examine the robustness of the SMD estimates, we also conducted a second meta-analysis using change-from-baseline values.²⁹ If the change-from-baseline values were not reported in the included studies and not obtained from the first authors, the OpenMetaAnalyst were used to calculate them from the available data.³⁰ The

OpenMetaAnalyst uses a correlation coefficient to impute a standard deviation of the change-from-baseline value:³⁰

$$SD_{E,change} = \sqrt{SD_{E,baseline}^2 + SD_{E,final}^2 - (2 \times Corr \times SD_{E,baseline} \times SD_{E,final})}$$

A funnel plot was conducted to detect potential publication bias.

3.6 References

1. Uman LS. Systematic reviews and meta-analyses. *J Can Acad Child Adolesc Psychiatry*. 2011;20(1):57-59.
2. Haidich A-B. Meta-analysis in medical research. *Hippokratia*. 2010;14(Suppl 1):29.
3. Impellizzeri FM, Bizzini M. Systematic review and meta-analysis: a primer. *International Journal of Sports Physical Therapy*. 2012;7(5):493.
4. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Journal of Clinical Epidemiology*. 2009;62(10):e1-e34.
5. Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*. 2017;358.
6. Higgins J, Thomas J, Chandler J. *Cochrane Handbook for Systematic Reviews of Interventions version 6.1*. Updated September 2020.
7. Kendall JM. Designing a research project: randomised controlled trials and their principles. *Emerg Med J*. 2003;20(2):164-168.
8. Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther*. 2003;83(8):713-721.
9. Scheffer AC, Schuurmans MJ, VanDijk N, Van Der Hooft T, De Rooij SE. Reliability and validity of the visual analogue scale for fear of falling in older persons. *Journal of the American Geriatrics Society*. 2010;58(11):2228-2230.
10. Tinetti ME, Richman D, Powell L. Falls efficacy as a measure of fear of falling. *Journal of Gerontology*. 1990;45(6):P239-P243.
11. Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing*. 2005;34(6):614-619.
12. Kempen GJM, Yardley L, Van Haastregt JCM, et al. The Short FES-I: a shortened version of the falls efficacy scale-international to assess fear of falling. *Age and Ageing*. 2007;37(1):45-50.
13. Powell LE, Myers AM. The Activities-specific Balance Confidence (ABC) Scale. *The Journals of Gerontology: Series A*. 1995;50A(1):M28-M34.
14. Lachman ME, Howland J, Tennstedt S, Jette A, Assmann S, Peterson EW. Fear of Falling and Activity Restriction: The Survey of Activities and Fear of Falling in the Elderly (SAFE). *The Journals of Gerontology: Series B*. 1998;53B(1):P43-P50.
15. Huang T-T. Geriatric fear of falling measure: development and psychometric testing. *International Journal of Nursing Studies*. 2006;43(3):357-365.
16. Dayhoff N, Baird C, Bennett S, Backer J. Fear of falling: measuring fear and appraisals of potential harm. *Rehabilitation Nursing Research*. 1994;3(3):97-104.
17. Simpson JM, Worsfold C, Fisher KD, Valentine JD. The CONFBal scale: a measure of balance confidence—a key outcome of rehabilitation. *Physiotherapy*. 2009;95(2):103-109.
18. Ammann BC, Knols RH, Baschung P, de Bie RA, de Bruin ED. Application of principles of exercise training in sub-acute and chronic stroke survivors: a systematic review. *BMC Neurology*. 2014;14(1):167.
19. Neil-Sztramko SE, Winters-Stone KM, Bland KA, Campbell KL. Updated systematic review of exercise studies in breast cancer survivors: attention to the principles of exercise training. *British Journal of Sports Medicine*. 2019;53(8):504.
20. Baschung Pfister P, de Bruin ED, Tobler-Ammann BC, Maurer B, Knols RH. The relevance of applying exercise training principles when designing therapeutic

- interventions for patients with inflammatory myopathies: a systematic review. *Rheumatology International*. 2015;35(10):1641-1654.
21. Hawley-Hague H, Horne M, Skelton D, Todd C. Review of how we should define (and measure) adherence in studies examining older adults' participation in exercise classes. *BMJ*. 2016;6(6):e011560.
 22. Blobaum P. Physiotherapy Evidence Database (PEDro). *J Med Libr Assoc*. 2006;94(4):477-478.
 23. Prictor M, Hill S. Cochrane consumers and communication review group: leading the field on health communication evidence. *Journal of Evidence-Based Medicine*. 2013;6(4):216-220.
 24. Landis JR, Koch GG. The Measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159-174.
 25. Cochrane Collaboration. *Review Manager (RevMan)*. Version 4.2 for Windows. Oxford, England: The Cochrane Collaboration; 2002.
 26. Higgins JP, Thomas J, Chandler J, et al. *Cochrane handbook for systematic reviews of interventions*. John Wiley & Sons; 2019.
 27. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. *BMC Medical Research Methodology*. 2005;5(1):13.
 28. Kendrick D, Kumar A, Carpenter H, et al. Exercise for reducing fear of falling in older people living in the community. *Cochrane Library*. 2014;2015(11):CD009848-CD009848.
 29. Fu R, Holmer HK. Change score or followup score? An empirical evaluation of the impact of choice of mean difference estimates. 2015.
 30. Wallace BC, Dahabreh IJ, Trikalinos TA, Lau J, Trow P, Schmid CH. Closing the gap between methodologists and end-users: R as a computational back-end. *Journal of Statistical Software*. 2012;49(1):1-15.

Chapter 4

Results

4.1 Study Selection

A total of 582 studies were identified through systematic searching. After removing 138 duplicates, 444 studies remained. Eleven additional studies were identified through AutoAlert. Fifty-six studies were identified through manually searching the reference lists of identified relevant articles and systematic reviews. In the abstract and title screening, 353 out of 511 studies were excluded because they did not meet the eligibility criteria. This yielded 158 studies for the full-text review. At this stage, 78 additional studies were excluded because participants were younger than 65 years old (31 studies), lived in a supported-living environment such as a nursing home (18 studies), the study design was not RCT (n=24), interventions were not exercises (n=4), or there was no FOF related outcome measure (n=1). During the data extraction, two studies were excluded due to non-RCT study design and three due to identical data sources (duplication of data from other RCTs). There were three articles and two articles in each group reporting on the same trials, and the earliest publications among them were included.^{1,2} A total of 75 trials were included in the qualitative review, out of which 50 trials were eligible and had enough post-intervention data for the meta-analysis (Figure 1).

Figure 1: Flow chart of the study selection process

4.2 Study Characteristics

The 75 included studies were published between 1997 and 2019, and the trials were most frequently conducted in the United States (25%), Australia (16%), and Germany (6.4%). The

sample sizes of the trials ranged from 6 participants to 1254 participants (median = 80 [interquartile range = 45–239]), and the mean age of the participants was 77 years. Women represented more than half of the participants in 56 trials. Forty-two trials assessed FOF as the primary outcome measure. The median duration of the interventions and full studies were 12 (interquartile range = 10–24) and 24 (interquartile range = 12–48) weeks, respectively (Table 3). Twenty-six trials used the Activities-specific Balance Confidence Scale (ABC) as a FOF outcome measure; the Falls Efficacy Scale-International (FES-I) and FES were used in 19 and 17 trials, respectively. Additional FOF measures used in less than 10% of the trials included a single-item question,³⁻⁷ a measure of balance confidence (CONFbal),¹ a visual analog scale (VAS),⁸⁻¹⁰ and the Survey of Activities and Fear of falling in the Elderly (SAFE).^{11,12}

Table 3: Study characteristics

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Arai, T (2007) ¹³	Japan	74.1	171	n	2-arms single-blind	y	12	12	2
Arantes, M (2015) ¹⁴	Brazil	73.05	30	100%	2-arms single-blind	y	12	12	2
Arkkukangas, M (2015) ¹⁵	Sweden	83	45	71%	3-arms single-blind	y	12	12	2
Arkkukangas, M (2019) ¹⁶	Sweden	83	175	70%	3-arms single-blind	y	12	96	4
Bao, T (2018) ¹⁷	USA	75.6	12	66%	2-arms single blind	y	8	8	3
Barban, F (2017) ¹⁸	Italy, Greece, Spain, Serbia	75	481	65%	4-arms single-blind	y	12	24	3
Barnett, A (2003) ³	Australia	74.9	163	66%	2-arms single-blinded	n	48	48	3
Beyer, N (2007) ¹⁹	UK	78.1	65	100%	2-arms open	y	24	48	3

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Boogird (2017) ²⁰	Thailand	74.37	439	82%	2-arms single blinded	n	48	48	5
Brouwer, B (2003) ²¹	Canada	77.55	34	74%	2-arms single blinded	y	8	8	3
Campbell, A. J (1997) ²²	New Zealand	84.1	233	100%	2-arms single-blind	n	48	48	3
Clemson, L (2012) ²³	Australia	83.4	317	55%	3-arms single-blind	n	24	48	3
Clemson, L (2010) ²⁴	Australia	81.53	34	47%	2-arms single-blind	n	24	24	3
Cockayne, S (2017) ²⁵	UK	78.1	1010	58%	2-arms double blinded	n	48	48	4
Covill, L (2017) ²⁶	USA	73.74	48	78%	2-arms open	y	n	n	4
Cyarto, E. V (2008) ²⁷	Australia	78.7	167	81%	3-arms single blinded	y	20	20	2
Devereux, K (2005) ²⁸	Australia	73.3	50	100%	2-arms open	y	10	10	2
Donath, L (2014) ²⁹	Switzerlan d	72.3	18	94%	2-arms open	y	6	6	2

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Duque, G (2013) ¹¹	Australia	76.84	70	61%	2-arms single-blind	y	6	36	3
El-Khoury, F (2015) ³⁰	France	79.7	706	100%	2-arms open	n	96	96	3
Freiberger, E (2013) ³¹	Germany	78.1	378	75%	2-arms open	y	16	96	4
Freiberger, E (2012) ³²	Germany	76.1	280	44%	4 arms single blinded	y	16	96	4
Gallo, E (2018) ³³	USA	75	35	46%	2-arms open	n	26	26	4
Gine-Garriga, M (2013) ³⁴	Spain	84	51	30%	2-arms open	y	12	36	3
Gitlin,L.N (2006) ³⁵	USA	79	319	81%	2-arms open	y	24	48	3
Gschwind, Y (2015) ³⁶	German, Spain, Australia	74.7	153	61%	2-arms open	y	16	24	2
Haines,T.P (2009) ³⁷	Australia	80.6	53	60%	2-arms single blinded	y	24	24	3

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Halvarsson, A (2011) ³⁸	Sweden	77	59	71%	2-arms single blinded	y	12	12	2
Hauer, K (2001) ³⁹	Germany	82.2	57	100%	2-arms single-blind	n	12	24	3
Henwood, T. R (2008) ⁴⁰	Australia	68.56	67	54%	3 arms open	n	24	24	3
Iliffe, S (2014) ¹	UK	72.94	1254	62%	3 arms open	n	24	96	5
Jagdhane, S (2016) ⁴¹	USA	73.3	6	83%	2-arms open	n	4	4	2
Jeon, M. Y (2014) ⁴²	Korea	69.24	62	100%	2-arms single blinded	y	12	12	2
Josephs, S (2016) ⁴³	USA	75.1	24	75%	2-arms single blinded	y	12	12	2
Kapan, A (2016) ⁴⁴	Austria	82.74	80	84%	2-arms open	y	12	12	2
Karinkanta, S (2012) ⁸	Finland	72.7	149	100%	4-arms open	y	48	48	3
Kim, S (2009) ⁴	USA	73.67	18	n	3-arms open	y	8	8	2

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Kyrdalen, I. L (2014) ⁴⁵	Norway	82.5	125	73%	2-arms single-blind	n	12	24	3
Lai, C.H (2013) ⁴⁶	Taiwan	72.7	30	57%	2-arms single-blind	y	6	12	3
LaStayo, P (2017) ⁴⁷	USA	76.1	134	65%	2-arms open	y	12	48	4
Li, F (2005) ¹²	USA	77.48	256	n	2-arms open	y	24	24	3
Li, F&Harmer (2005) ⁴⁸	USA	77.8	256	70%	2-arms open	n	26	48	6
Li, F (2019) ⁴⁹	USA	77.7	670	65%	2-arms single-blind	y	24	48	3
Lin, M.R (2007) ⁹	Taiwan	76.8	150	51%	3-arm single blinded	n	16	16	3
Liu, H (2007) ⁵⁰	USA	80.73	26	64%	2-arm double blinded	y	12	12	2
Liu, Y. W (2014) ⁵¹	China	74.5	122	87%	2-arm single blinded	y	8	16	3
Liu-Ambrose, T (2004) ⁵²	Canada	79	104	100%	3-arms open	y	13	13	2

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Logghe, I. H. J (2009) ⁵³	Netherlands	77	269	71%	2-arm single blinded	n	13	48	4
McCormack, G (2004) ⁵⁴	Australia	79.1	43	n	3-arms open	y	10	10	2
Oh, S (2015) ⁵⁵	Korea	71.56	80	n	2-arm single blinded	y	10	10	2
Okubo, Y (2016) ⁵⁶	Japan	70.1	90	62%	2-arms open	n	12	52	3
Patil, R (2016) ⁵⁷	Finland	74.2	409	100%	4-arms double blinded	y	96	96	3
Plummer- D'Amato, P (2012) ⁵⁸	USA	76.64	20	94%	2-arm single blinded	y	4	4	2
Pollock, R. D (2012) ⁵⁹	UK	81.01	77	32%	2-arms single-blind	n	8	24	4
Roller, M (2017) ⁶⁰	USA	77.6	55	69%	2-arms single-blinded	y	10	10	2
Sattin, R. W (2005) ⁶¹	USA	80.86	311	94%	2-arms single-blind	y	48	48	4

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Schoene, D (2015) ⁶²	Australia	81.5	90	67%	2-arms single-blind	n	16	16	2
Shigematsu, R (2008) ⁵	Japan	69.04	39	46%	2-arms open	y	12	56	2
Siegrist, M (2016) ⁶³	Germany	78.1	378	75%	2-arms open	n	16	96	4
Smulders, E (2010) ⁶⁴	Netherlands	71	96	94%	2-arms single-blind	n	5.5	48	3
Szturm, T (2011) ⁶⁵	Canada	n/a	30	n	2-arm single blinded	y	8	8	2
Ullmann, G (2010) ⁶⁶	USA	75.6	47	70%	2-arms open	y	5	5	2
Vogler (2009) ⁶⁷	Australia	80	180	79%	3-arms single-blind	n	12	12	2
Voukelatos, A (2015) ⁶⁸	Australia	73.2	386	74%	2-arms open	n	48	48	4
Westlake, K. P (2007) ⁶⁹	USA	n/a	44	n	3 arms single blinded	n	8	16	3
Wetherell, J. L (2018) ⁷⁰	USA	77.9	42	74%	2-arms single blinded	y	8	18	7

First Authors (year)	Country	Mean age	Sample size	Women %	Design	Is FOF primary outcome	Duration of intervention (Weeks)	Duration of study (weeks)	# of assessments during study
Wolf, B (2001) ¹⁰	Netherlands	84.3	77	73%	2-arms single-blind	y	6	48	4
Wolf, S. L (2003) ⁶	USA	76.2	200	81%	3-arms open	n	15	31	3
Wollesen, B (2017) ⁷¹	Germany	71.5	95	77%	4-arms single-blind	n	12	12	2
Wu, G (2010) ⁷²	USA	75.4	64	n	3-arms open	y	15	15	2
Yamada, M (2011) ⁷	Japan	71.8	57	n	2-arms single blinded	y	24	24	2
Yang, X. J (2012) ⁷³	Australia	85.55	165	44%	2-arms single-blind	n	24	24	2
Yoo, E. J (2010) ⁷⁴	Korea	70.1	21	n	2-arm open	y	12	12	2
Zhang, L (2014) ⁷⁵	China	85.27	44	14%	2-arms single-blind	n	8	8	3
Zhao, Y (2016) ⁷⁶	China	70	61	69%	2-arms single-blinded	n	16	24	4

Note. y: yes; n: not reported; n/a: not applicable

4.3 Reporting of Principles of Exercise Training

The ratings of application principles of exercise training of all trials are listed in Table 4. None of the 75 trials reported information for all the six principles. Three trials reported five principles, 21 trials reported four, 21 trials reported three, 18 trials reported two, 11 trials reported one, and one trial reported none of them.

The specificity was reported in 69 trials, while the initial value was only reported in 6 trials. The second most frequently reported principle was progression in 54 trials. Overload and reversibility were reported in less than 50% of trials, and diminishing return was reported in 21% of trials (Figure. 2).

The agreement between the 2 reviewers (C.F. and T.A.) in rating principles of exercise training was almost perfect ($\kappa = 0.94$).

Figure 2: Reporting of principles of exercise training

4.4 Reporting of FITT Components and Adherence

Frequency was reported in 67 trials, intensity was reported in 19 trials, time was reported in 64 trials, the type was reported in 73 trials, and adherence to exercise interventions was reported in 47 trials (Figure. 3).

The agreement for assessing FITT components and adherence was substantial ($\kappa = 0.79$).

Figure 3: Reporting of FITT components and adherence

Table 4: Reporting of principles of exercise training and FITT

Fist Author. Year	Sp	Pr	OL	IV	Re	DR	F	I	T	T
Arai, T. 2007	y	y	y	y	n	n	y	y	y	y
Arantes, M. 2015	y	y	y	n	n	n	y	unclear	y	y
Arkkukangas, M.2015	y	y	y	n	n	n	y	n	y	y
Arkkukangas, M.2019	y	y	y	n	y	n	y	unclear	y	y
Bao, T. 2018	y	y	y	n	n	y	y	y	y	y
Barban, F.2017	y	y	n	n	y	n	y	n	y	y
Barnett, A. 2003	y	y	n	n	n	n	n	n	n	y
Beyer, N. 2007	y	y	y	n	y	y	y	y	y	y
Boongird. 2017	y	y	n	n	n	y	n	n	n	y
Brouwer, B. 2003	y	n	n	n	y	n	y	n	y	y
Campbell, A. J.1997	y	y	n	n	y	n	y	unclear	y	y
Clemson, L.2012	y	y	y	n	y	n	y	unclear	n	y
Clemson, L.2010	y	y	n	n	n	y	n	n	n	y
Cockayne, S. 2017	y	n	n	n	n	n	y	y	y	y
Covill, L. 2017	y	y	y	n	y	n	n	n	y	y
Cyarto, E. V. 2008	y	y	y	n	n	n	y	n	y	y
Devereux, K. 2005	y	n	n	n	n	n	y	n	y	y
Donath, L. 2014	y	y	n	n	n	n	y	n	y	y

Duque, G.2013	y	y	y	n	y	n	y	y	y	y
El-Khoury, F. 2015	y	y	n	n	y	n	y	unclear	y	y
Freiberger, E. 2013	y	y	n	n	n	n	y	unclear	y	y
Freiberger, E. 2012	y	y	n	n	y	y	y	unclear	y	y
Gallo, E.2018	y	y	y	n	n	y	y	unclear	y	y
Gine-Garriga, M. 2013	y	y	y	n	y	n	y	y	n	y
Gitlin, L. N. 2006	y	n	n	n	y	n	n	n	n	y
Gschwind, Y.2015	y	y	y	y	n	n	y	unclear	y	y
Haines, T. P. 2009	y	y	y	n	y	y	n	n	n	y
Halvarsson, A. 2011	y	y	y	y	n	n	y	n	y	y
Hauer, K.2001	y	y	y	n	y	n	y	y	y	y
Henwood, T. R. 2008	y	y	y	n	n	y	y	y	y	y
Illiffe, S. 2014	y	y	y	y	y	n	y	unclear	y	y
Jagdhane, S. 2016	y	y	n	n	n	n	y	unclear	y	y
Jeon, M. Y. 2014	y	n	n	n	n	n	y	n	y	y
Josephs, S. 2016	y	y	y	n	n	n	y	y	y	y
Kapan, A. 2016	y	n	n	n	n	n	y	n	y	y
Karinkanta, S. 2012	y	y	y	n	y	n	y	y	y	y
Kim, S. 2009	y	y	y	n	n	n	y	y	y	y
Kyrdalen, I. L.2014	y	y	y	n	y	n	y	n	y	y
Lai, C.H.2013	n	n	n	n	n	n	y	n	y	n
LaStayo, P. 2017	y	y	y	n	y	n	y	y	y	y
Li, F. 2005	y	n	n	n	n	y	y	unclear	y	y
Li, F&Harmer.2005	y	n	n	n	y	y	n	n	n	y
Li, F.2019	y	n	n	n	y	n	y	n	y	y
Lin, M. R. 2007	y	y	y	n	y	n	y	n	y	y
Liu, H. 2007	y	y	y	n	n	n	y	unclear	y	y
Liu, Y. W. 2014	n	n	n	n	y	n	y	n	y	y
Liu-Ambrose, T. 2004	y	y	y	n	n	n	y	y	y	y
Logghe, I. H. J. 2009	n	n	n	n	y	n	y	n	y	y
McCormack, G.2004	y	y	n	n	n	n	y	unclear	y	y
Oh, S. 2015	y	n	n	n	n	n	y	y	y	y
Okubo, Y.2016	y	y	n	n	y	n	y	y	y	y
Patil, R. 2016	y	y	n	n	y	y	y	y	y	y
Plummer. 2012	y	y	n	n	n	n	y	n	y	y
Pollock, R. D.2012	y	y	n	n	y	y	y	n	y	y
Roller, M. 2018	y	y	y	n	n	n	y	n	y	y

Sattin, R. W. 2005	y	y	n	y	n	y	y	n	y	y
Schoene, D.2015	y	y	y	y	n	n	y	unclear	y	y
Shigematsu, R. 2008	y	y	n	n	n	n	y	n	y	y
Siegrist, M. 2016	y	y	n	n	n	n	y	n	y	y
Smulders, E.2010	y	n	n	n	y	n	y	n	y	y
Szturm, T. 2011	y	y	n	n	n	n	y	n	y	y
Ullmann, G. 2010	y	n	y	n	n	n	y	n	y	y
Vogler.2009	y	y	n	n	n	n	y	y	n	y
Voukelatos, A.2015	n	y	n	n	n	n	n	unclear	n	y
Westlake, K. P. 2007	y	y	n	n	y	n	y	n	y	y
Wetherell, J. L. 2018	y	n	n	n	y	y	y	n	y	y
Wolf, B.2001	y	n	n	n	y	n	y	n	y	y
Wolf, S. L. 2003	y	y	n	n	y	n	y	n	y	y
Wollesen, B. 2017	y	y	n	n	n	n	y	n	y	y
Wu, G. 2010	y	n	n	n	n	n	y	n	y	y
Yamada, M. 2011	y	y	y	n	n	n	y	unclear	y	y
Yang, X. J.2012	y	y	y	n	n	n	y	n	y	y
Yoo, E. J. 2010	y	n	n	n	n	n	y	y	y	y
Zhang, L.2014	n	n	n	n	n	y	y	n	n	n
Zhao, Y. 2016	y	n	n	n	y	y	y	y	y	y

Note. y: yest; n: not reported; Sp: specificity; Pr: progression; OL: overload; IV: initial value; Re: reversibility; DR: diminishing return; F: frequency; I: intensity; T: time; T: type of exercise

4.5 Rating of the Methodological Quality of Included RCTs

No trials had excellent methodological quality. Forty-seven and 27 trials had good and fair methodological quality, respectively. One trial was rated as having poor methodological quality (Table 5).

All trials met criterion 2 (randomization), 74 trials met criterion 10 (between-group comparisons), and 72 trials followed criterion 11 (point estimates and variability). However, none of the trials masked all participants and therapists. Thirty-one trials reported concealed allocation, and 46 trials masked assessors. Finally, 42 trials measured at least one key outcome in more than 85% of participants, and 39 trials used an intention-to-treat analysis (Table 6).

The agreement in rating the PEDro Scale between the 2 reviewers was excellent ($\kappa = 0.88$).

Table 5. PEDro scores

PEDro Criteria:	1	2	3	4	5	6	7	8	9	10	11	Total 10/10
Arai, T. 2007	1	1	0	1	0	0	1	0	0	1	1	5/10
Arantes, M. 2015	1	1	1	1	0	0	1	1	0	1	1	7/10
Arkkukangas, M.2015	1	1	0	1	0	0	1	1	0	1	1	6/10
Arkkukangas, M.2019	1	1	0	1	0	0	1	1	1	1	1	7/10
Bao, T. 2018	1	1	1	1	0	0	1	1	0	1	1	7/10
Barban, F.2017	1	1	1	1	0	0	1	1	0	1	1	7/10
Barnett, A. 2003	1	1	1	1	0	0	1	1	1	1	1	8/10
Beyer, N. 2007	1	1	0	1	0	0	0	0	1	1	1	5/10
Boongird. 2017	1	1	1	1	0	0	0	1	0	1	1	6/10
Brouwer, B. 2003	1	1	0	1	0	0	1	1	0	1	1	6/10
Campbell, A. J.1997	1	1	1	1	0	0	1	1	1	1	1	8/10
Clemson, L.2012	1	1	1	1	0	0	1	0	1	1	1	7/10
Clemson, L.2010	1	1	1	1	0	0	1	1	1	1	1	8/10
Cockayne, S. 2017	1	1	1	1	0	0	0	1	1	1	1	7/10
Covill, L. 2017	1	1	0	1	0	0	0	0	0	1	1	4/10
Cyarto, E. V. 2008	1	1	1	0	0	0	1	1	1	1	1	7/10
Devereux, K. 2005	1	1	1	1	0	0	0	1	1	1	1	7/10
Donath, L. 2014	0	1	0	1	0	0	0	1	0	1	1	5/10
Duque, G.2013	1	1	0	1	0	0	1	0	0	1	1	5/10
El-Khoury, F. 2015	1	1	1	1	0	0	1	1	1	1	1	8/10
Freiberger, E. 2013	1	1	0	1	0	0	0	1	0	1	1	5/10
Freiberger, E. 2012	1	1	1	1	0	0	1	1	1	1	1	8/10
Gallo, E.2018	1	1	0	1	0	0	0	0	0	1	1	4/10
Gine-Garriga, M. 2013	1	1	0	1	0	0	0	0	1	1	1	5/10
Gitlin, L. N. 2006	1	1	1	1	0	0	0	1	1	1	1	7/10
Gschwind, Y.2015	0	1	0	1	0	0	0	1	1	1	1	6/10
Haines, T. P. 2009	1	1	1	1	0	0	1	1	0	1	1	7/10
Halvarsson, A. 2011	1	1	1	1	0	0	1	1	0	1	1	7/10
Hauer, K.2001	1	1	0	1	0	0	1	0	1	1	1	6/10
Henwood, T. R. 2008	1	1	0	1	0	0	0	0	0	1	1	4/10
Ilfte, S. 2014	1	1	1	1	0	0	0	0	1	1	1	6/10

PEDro Criteria:	1	2	3	4	5	6	7	8	9	10	11	Total 10/10
Jagdhane, S. 2016	0	1	0	1	0	0	0	0	0	1	1	4/10
Jeon, M. Y. 2014	0	1	0	1	0	0	1	1	0	1	1	6/10
Josephs, S. 2016	1	1	0	1	0	0	1	0	0	1	1	5/10
Kapan, A. 2016	1	1	0	1	0	0	0	0	1	1	1	5/10
Karinkanta, S. 2012	1	1	0	1	0	0	0	1	1	1	1	6/10
Kim, S. 2009	1	1	0	0	0	0	0	0	0	1	0	2/10
Kyrdalen, I. L.2014	1	1	0	1	0	0	1	0	1	1	1	6/10
Lai, C.H.2013	0	1	0	1	0	0	1	0	0	0	1	4/10
LaStayo, P. 2017	1	1	0	1	0	0	1	1	1	1	1	7/10
Li, F. 2005	1	1	0	1	0	0	0	0	1	1	1	5/10
Li, F&Harmer.2005	1	1	0	1	0	0	0	0	1	1	1	5/10
Li, F.2019	0	1	0	0	0	0	1	1	1	1	1	6/10
Lin, M. R. 2007	1	1	0	1	0	0	1	0	0	1	1	5/10
Liu, H. 2007	1	1	0	1	0	0	1	0	0	1	0	4/10
Liu, Y. W. 2014	1	1	1	1	0	0	1	0	1	1	1	7/10
Liu-Ambrose, T. 2004	1	1	0	1	0	0	0	1	0	1	1	5/10
Logghe, I. H. J. 2009	1	1	1	1	0	0	1	1	1	1	1	8/10
McCormack, G.2004	1	1	0	1	0	0	0	0	0	1	1	4/10
Oh, S. 2015	1	1	0	1	0	0	1	0	0	1	1	5/10
Okubo, Y.2016	1	1	0	1	0	0	0	1	0	1	1	5/10
Patil, R. 2016	1	1	0	1	0	0	1	1	1	1	1	7/10
Plummer. 2012	1	1	1	1	0	0	1	1	0	1	1	7/10
Pollock, R. D.2012	1	1	1	1	0	0	1	0	0	1	1	6/10
Roller, M. 2018	1	1	0	1	0	0	1	1	0	1	1	6/10
Sattin, R. W. 2005	1	1	0	1	0	0	1	0	1	1	1	6/10
Schoene, D.2015	1	1	0	1	0	0	1	1	1	1	1	7/10
Shigematsu, R. 2008	1	1	0	1	0	0	0	1	1	1	1	6/10
Siegrist, M. 2016	1	1	0	1	0	0	0	0	0	1	1	4/10
Smulders, E.2010	1	1	1	1	0	0	1	1	1	1	1	8/10
Szturm, T. 2011	1	1	1	1	0	0	1	1	0	1	1	7/10
Ullmann, G. 2010	1	1	0	1	0	0	0	0	1	1	1	5/10
Vogler.2009	1	1	1	1	0	0	1	1	1	1	1	8/10
Voukelatos, A.2015	1	1	1	1	0	0	0	0	1	1	1	6/10
Westlake, K. P. 2007	1	1	0	1	0	0	0	0	0	1	1	4/10
Wetherell, J. L. 2018	1	1	1	1	0	0	1	1	1	1	1	8/10

PEDro Criteria:	1	2	3	4	5	6	7	8	9	10	11	Total 10/10
Wolf, B.2001	1	1	1	1	0	0	1	1	1	1	1	8/10
Wolf, S. L. 2003	1	1	0	1	0	0	1	1	0	1	1	6/10
Wollesen, B. 2017	1	1	0	1	0	0	1	1	0	1	0	5/10
Wu, G. 2010	1	1	0	1	0	0	0	0	1	1	1	5/10
Yamada, M. 2011	1	1	1	1	0	0	1	1	0	1	1	7/10
Yang, X. J.2012	1	1	1	1	0	0	1	0	1	1	1	7/10
Yoo, E. J. 2010	1	1	0	1	0	0	0	0	0	1	1	4/10
Zhang, L.2014	1	1	1	1	0	0	1	0	1	1	1	7/10
Zhao, Y. 2016	1	1	1	1	0	0	1	1	1	1	1	8/10

Table 6: The number (%) of trials meeting each criterion of PEDro scale

PEDro criteria	Number (%)
1. eligibility criteria were specified	69 (92%)
2. subjects were randomly allocated to groups (in a crossover study, subjects	75 (100%)
3. allocation was concealed	31 (41%)
4. the groups were similar at baseline regarding the most important prognostic	72 (96%)
5. there was blinding of all subjects	0 (0%)
6. there was blinding of all therapists who administered the therapy	0 (0%)
7. there was blinding of all assessors who measured at least one key outcome	46 (61%)
8. measures of at least one key outcome were obtained from more than 85%	42 (56%)
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by “intention to treat”	39 (52%)
10. the results of between-group statistical comparisons are reported for at least one	74 (99%)
11. the study provides both point measures and measures of variability for at least one key outcome	72 (96%)

4.6 Exercise Prescription

Table 7 illustrates the detailed characteristics of exercise prescription for all trials. Thirty-three trials applied multicomponent exercise interventions (e.g., balance, resistance, endurance, and coordination), 14 used balance exercises, 11 used three-dimensional (3D) exercises (i.e., Tai

Chi and Pilates), seven used strengthening exercises, four used aerobic exercises, and six used novel exercises (i.e., water-based exercise, Feldenkrais, video games, whole-body vibration, and fall training). Fifty-two trials explicitly reported the repetition/duration and sets of the exercises, and 16 trials provided values for the intensity of the exercise interventions. The intensity was mainly measured with the 1 Repetition Maximum (1RM) for strengthening exercise; the Borg Scale for the Rating of Perceived Exertion (RPE) for strengthening, balance, and multicomponent exercises; or the Maximum Heart Rate (HR max) for aerobic exercise. No adverse effects of exercise interventions were reported in the included trials.

The exercise dosage varied across the 75 trials. The mode of exercise frequency was 3 times per week for 12 weeks. The intensity was between 30% and 85% of the 1RM and 7 to 14 on the RPE. The duration of each exercise session was between 15 and 135 minutes (median = 60 [interquartile range = 45–60]). The most common types of equipment used in the trials were ankle weights, resistive bands, different exercise balls (e.g., stability ball and medicine ball), and stability trainers.

Among 47 trials that showed significant intragroup or intergroup improvements in FOF outcome measures, most trials used multicomponent exercises (23 trials) and group-based interventions, moderate-intensity (a RPE of 12 or 13, an HR max of 64%–76%, or a 1RM of 60%–70%), 3 times per week for 12 to 16 weeks, and 30 to 60 minutes for each exercise session.

Table 8 is a summary of the main findings in included studies. No patterns were observed regarding the relationship between the significant outcomes in FOF reduction and other variables (i.e., significance on physical performance outcomes, number of exercise principles reported in each study, number of FITT reported in each study, and PEDro scores).

Table 7: Exercise prescription characteristics

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
Arai, T. 2007	Resistance&balance &functional	n	>60% of 1RM	2*12	90	10-15mins	10min
Arantes, M. 2015	Balance	0.5min*4; 15*2	Maintain challenging	2*12	60	n	n
Arkkukangas, M.2015	OEP	n	n	3*12	30	n	n
Arkkukangas, M.2019	OEP	n	unclear	3*12	30	n	n
Bao, T. 2018	Balance exercises	30s*6	VAS of 3	3*8	45	n	n
Barban, F.2017	Balance&Gait	n	n	2*12	60	y	n
Barnett, A. 2003	Balance&Coordination&Aer obic&Strength	n	n	n	n	5-10min	10min
Beyer, N. 2007	Strength&Balance	10reps*3	70-75% 1RM	2*24	60	10min	5min
Boogird. 2017	Modified-OEP	n	n	n	n	n	n
Brouwer, B. 2003	Low-resistance	n	n	1*8	60	10min	10min
Campbell, A. J.1997	Strength&Balance	n	unclear	3*48	30	n	n
Clemson, L.2012	Balance&Strength	n	unclear	3*48	n	n	n

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
Clemson, L.2010	Balance&Strength	n	n	n	n	n	n
Cockayne, S. 2017	Foot and ankle exercises	10*3	n	3*24	30	n	n
Covill, L. 2017	Tai Chi	n	n	n	30-40	5-10min	5min
Cyarto, E. V. 2008	Group resistance	n	n	2*20	60	y	10min
	Home balance	5-15*2					
Devereux, K. 2005	Water-based exercise	n	n	2*10	50min	n	n
Donath, L. 2014	Fall-training	n	n	2*6	60	10min	5min
Duque, G.2013	Balance	n	15 levels	2*6	30	n	n
El-Khoury, F. 2015	Balance	n	Increase in intensity	1*96	60	n	n
Freiberger, E. 2013	Strength&Balance&Endurance	n	RPE	1*16	60	10min	5-10min
Freiberger, E. 2012	Strength&Balance&Endurance	n	RPE	1*16	60	10min	10min
Gallo, E.2018	Balance&Gait	n	unclear	5*26	24	n	n
Gine-Garriga, M. 2013	Functional balance	unclear*4	n	1*12	n	10min	5min

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
	-strength	6-8-15reps*1-2	RPE 12–14	1*12	n		
Gitlin,L.N. 2006	Balance&Strength	n	n	n	n	n	n
Gschwind, Y.2015	Balance&Strength	10-15reps*2-3	unclear	6*16	60	n	n
Haines, T.P. 2009	Strength&Balance	3-10reps*1	n	n	n	n	n
Halvarsson, A. 2011	Balance with dual or multi- tasks	n	n	3*12	45	y	y
Hauer, K.2001	Resistance&Balance	10-15reps*2-3	79-90% MW	3*12	135	10min	n
Henwood, T. R. 2008	Conditioning		65%-70% 1RM				
	Strength	8*3	75% 1RM	2*24	60	10min	y
	High-velocity		40-75% 1RM				
Iliffe, S. 2014	FaME	n	More intense than OEP	3*24	90	n	n
	OEP		Moderate	3*24	30		
Jagdhane, S. 2016	APA-focused training	10min*3-4	unclear	3*4	60	5-7min	5-7min
Jeon,M.Y. 2014	Strength&Endurance&Balance	n	n	3*12	80	n	n

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
Josephs, S. 2016	Pilates	10rep*1	RPE12-14	2*12	60	n	n
	Resistance&Balance	Individualized					
Kapan, A. 2016	Balance&Strength	12-15reps*2	n	2*12	60	10min	n
Karinkanta, S. 2012	Resistance	10-15*2 Or 8-10*3	50-80%1RM; RPE18-20	3*48	40-50	7-10min	8-10min
	Balance-jumping	n	n				
	Resistance&Balance- jumping training	n	n				
Kim, S. 2009	Balance	n	n	3*8	50 to 60	n	n
	Strength	10*3-7*3	50%-85% ME				
Kyrdalen, I. L.2014	OEP	n	n	2*12	45	n	n
Lai, C.H.2013	interactive video-game based (IVGB) training	n	n	3*6	30	n	n
LaStayo, P. 2017	TRAD resistance	15*3:	60-70%1RM	3*12	60	n	n
	RENEW	3-15min	RPE7-13				
Li, F. 2005	Tai chi	n	n	3*26	60	5-10min	5-10min

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
	Stretching		Low intensity			n	n
Li, F&Harmer.2005	Tai Chi	n	n	3*26	n	5-10min	5-10min
Li, F.2019	Tai Ji Quan	4-5reps*3-6					
	Multimodal (Aerobics, Balance, Strength, Flexibility)	4-30rep*1	n	2*24	60	n	n
Lin, M.R. 2007	Strength&Balance	n	n	3*16	50	10	10
Liu, H. 2007	Resistance&Balance	10*1-2	individualized				
	ROM	5-10*2	Same intensity	3*12	60	5min	10-15min
Liu, Y. W. 2014	Tai chi	n	n	1*8	60	5	5
Liu-Ambrose, T. 2004	Resistance	10-15*2-6-8*2	50-85%1RM				
	Agility	n	n	2*13	50	n	n
	Stretching						
Logghe, I. H. J. 2009	Tai chi	n	n	2*13	60	y	y

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
McCormack, G.2004	Strength	n	Low intensity	2*10	30-45	y	y
Oh, S. 2014	Water-based	n	RPE 4/10	3*10	60	10min	10min
	Land-based						
Okubo, Y.2016	Brist walking	n/a	light-somewhat hard	3-5*12	30-50	10-15min	10-15min
	OEP&Tai Chi	10-20rep	n	3-5*12	45-60	n	n
Patil, R. 2016	Resistance&Balance& Agility&mobility	8-12*2	30-75%1RM; RPE14-18	2*48-1*48	60	10min	n
Plummer. 2012	Balance&Gait&Agility	n	n	1*4	45	n	n
Pollock, R. D.2012	Strength&Balance&Function al mobility	n	n	3*8	60	n	n
Roller, M. 2017	Pilates	10*1	n	1*10	45	n	n
Sattin, R. W. 2005	Tai Chi	n	n	2*48	60-90	y	y
Schoene, D.2015	Balance	n	unclear	3*16	20	n	n
Shigematsu, R. 2008	Square-stepping	n	n	2*12	70	15min	15min
	Strength&Balance	10*3					

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
Siegrist, M. 2016	Strength&Power&Balance& gait	n	n	1*16	60	n	n
Smulders, E.2010	Weight-bearing&walking	n	n	2*5.5	15-60	n	n
Szturm, T.	Balance	n	n	2*8	45	n	n
Ullmann, G. 2010	Feldenkrais	n	n	3*5	60	n	n
Vogler.2009	Seated exercise Weight bearing	10-12 reps	10-12RM	3*12	n	n	n
Voukelatos, A.2015	Walking	n	unclear	n	n	n	n
Westlake, K. P. 2007	Balance	n	n	3*8	60	n	n
Wetherell, J. L. 2018	Strength&Balance	n	n	1*8	60	n	n
Wolf, B.2001	Balance	n	n	2-3*4-6	30	n	n
Wolf, S. L. 2003	Tai Chi	n	n	14*15	>15	n	n
	Balance			n	n		
Wollesen, B. 2017	Dual task	n	n	1*12	60	n	n

Fist Author. year	Type of Exercises	Reps/Min*sets	Intensity	Frequency (times*weeks)	time(min/ session)	Warm Up	Cool Down
Wu, G. 2010	Tai Chi	n	n	3*15	60	y	n
Yamada, M. 2011	Rhythmic stepping	1-3-5min*3-5	Moderate	1*24	60	15 min	10 min
Yang, X. J.2012	Strength&Balance	10s*4	n	5*24	20	y	n
Yoo, E. J. 2010	Walking	n	60% HR	3*12	60	10 min	5 min
Zhang, L.2014	Whole-body vibration	n	n	3-5*8	n	n	n
Zhao, Y. 2016	Balance	n	RPE11-13	3*16	90	10-15min	10-15 min

Note. n: not reported; 1RM:1 repetition maximum; VAS: visual analogue scale; RPE: rating of perceived exertion; ME: maximum exertion; MW: maximum workload; OEP: Otago exercise programme including leg muscle strengthening and balance exercises; FaME: falls management exercise including balance, strength, endurance, flexibility, functional floor skills, and adapted Tai Chi; APA: anticipatory postural adjustments; TRAD: traditional resistance exercise; RENEW: resistance exercise via negative, eccentrically-induced work; ROM: range of motion.

Table 8: Summary of main findings in included studies

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Arai, T. 2007	FES	y	n	y	4	4	5
Arantes, M. 2015	FES-I	y	y	y	3	3	7

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Arkkukangas, M.2015	FES	y	n	n	3	3	6
Arkkukangas, M.2019	FES	y	n	n	4	3	7
Bao, T. 2018	ABC	n	n	y	4	4	7
Barban, F.2017	FES-I	y	y	y	3	3	7
Barnett, A. 2003	Single item	n	n	y	2	1	8
Beyer, N. 2007	ABC	y	n	y	5	4	5
Boongird. 2017	FES-I	y	y	n	3	1	6
Brouwer, B. 2003	ABC	y	y	y	2	3	6
Campbell, A. J.1997	FES	n	y	y	3	3	8
Clemson, L.2012	ABC	n	y	y	4	2	7
Clemson, L.2010	ABC/MFES	n	y	y	3	1	8
Cockayne, S. 2017	Short-FES-I	n	n	n/a	2	4	7
Covill, L. 2017	ABCI	n	n	y	4	2	4
Cyarto, E. V. 2008	ABC	y	y	y	3	3	7
Devereux, K. 2005	MFES	y	n	y	1	3	7
Donath, L. 2014	FES-I	y	n	n	2	3	5
Duque, G.2013	SAFE	y	y	y	4	4	5
El-Khoury, F. 2015	FES-I	n	n	y	3	3	8

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Freiberger, E. 2013	FES-I	y	y	y	2	3	5
Freiberger, E. 2012	ABC	y	n	y	4	3	8
Gallo, E.2018	ABC	n	y	y	4	3	4
Gine-Garriga, M. 2013	ABC	y	y	n/a	4	3	5
Gitlin, L. N. 2006	FES	n	y	y	2	1	7
Gschwind, Y.2015	Icon-FES	y	n	y	4	4	6
Haines, T. P. 2009	ABC	y	n	n	5	1	7
Halvarsson, A. 2011	FES-I	y	y	y	4	3	7
Hauer, K.2001	Subjective rating of FOF	n	y	y	4	4	6
Henwood, T. R. 2008	ABC	n	n	y	4	4	4
Iliffe, S. 2014	FES-I/CONFbal	n	y	n	5	3	6
Jagdhane, S. 2016	ABC	n	n	y	2	3	4
Jeon, M. Y. 2014	FES	y	y	y	1	3	6
Josephs, S. 2016	ABC	y	y	y	3	4	5
Kapan, A. 2016	FES-I	y	y	y	1	3	5

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Karinkanta, S. 2012	VAS	y	n	n/a	4	4	6
Kim, S. 2009	Single item	y	y	n/a	3	4	2
Kyrdalen, I. L.2014	FES-I	n	y	y	4	3	6
Lai, C.H.2013	MFES	y	y	y	0	2	4
LaStayo, P. 2017	ABC	y	y	n	4	4	7
Li, F. 2005	ABC	y	y	n/a	2	3	5
Li, F&Harmer.2005	SAFE	n	y	y	3	1	5
Li, F.2019	ABC	y	y	y	3	3	6
Lin, M. R. 2007	VAS	n	y	y	4	3	5
Liu, H. 2007	FES	y	y	y	3	3	4
Liu, Y. W. 2014	FES-I	y	y	n	1	3	7
Liu-Ambrose, T. 2004	ABC	y	y	n	3	4	5
Logghe, I. H. J. 2009	FES	y	n	n	1	3	8
McCormack, G.2004	MFES	y	y	n/a	1	3	4
Oh, S. 2015	MFES	y	y	y	1	4	5
Okubo, Y.2016	FES	n	y	y	3	4	5
Patil, R. 2016	FES-I	y	n	n	4	4	7
Plummer. 2012	ABC	n	n	y	2	3	7

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Pollock, R. D.2012	FES-I	n	y	y	4	3	6
Roller, M. 2018	ABC	y	n	y	3	3	6
Sattin, R. W. 2005	ABC	y	y	n/a	4	3	6
Schoene, D.2015	icon-FES	n	y	y	4	3	7
Shigematsu, R. 2008	Single item	n	n	y	2	3	6
Siegrist, M. 2016	FES-I	n	y	y	2	3	4
Smulders, E.2010	ABC	n	y	y	2	2	8
Szturm, T. 2011	ABC	n	y	y	2	3	7
Ullmann, G. 2010	FES	y	y	y	2	3	5
Vogler.2009	MFES	n	n	y	2	3	8
Voukelatos, A.2015	FES-I	n	n	y	1	1	6
Westlake, K. P. 2007	ABC	n	n	y	3	3	4
Wetherell, J. L. 2018	FES-I	y	y	n/a	3	3	8
Wolf, B.2001	VAS	y	n	y	2	3	8
Wolf, S. L. 2003	Single item	n	y	y	3	3	6
Wollesen, B. 2017	FES-I	n	n	y	2	3	5
Wu, G. 2010	ABC	n	y	y	1	3	5
Yamada, M. 2011	Single item	y	y	y	2	3	7

Fist Author. Year	FOF measure	Is FOF primary outcome measure	Significant reduction in FOF outcomes	Significance on physical performance measures	No. of EP reported	No. of FITT reported	PEDro score
Yang, X. J.2012	MFES	n	n	y	3	3	7
Yoo, E. J. 2010	FES	y	y	y	1	4	4
Zhang, L.2014	ABC	n	y	y	1	1	7
Zhao, Y. 2016	FES-I	y	y	y	3	4	8

Note. n: no; y: yes; n/a: not applicable. EP: exercise principles.

4.7 Meta-Analysis

4.7.1 Effectiveness of Exercise Interventions for FOF

According to the post-intervention data, the pooled estimate of the SMD in 50 studies with continuous data was -0.34 (95% CI = -0.44 to -0.23), with a substantial level of heterogeneity ($I^2 = 75\%$)⁷⁷ (Figure 4).

Figure 4: The pooled effect of exercise interventions on FOF using post-intervention data

4.7.2 Subgroup Analysis

Figure 5 to 9 illustrated the subgroup analyses for studies entered with post-intervention values. There was no statistically significant effect on any subgroups on the basis of type of exercise ($\chi^2 = 10.45$; $P = 0.06$), duration of interventions ($\chi^2 = 1.90$; $P = 0.39$), FOF as primary or secondary outcome measures ($\chi^2 = 0.5$; $P = 0.48$), and individual- or group-based exercises ($\chi^2 = 0.24$; $P = 0.62$).

However, studies that used balance exercise interventions (19 studies: SMD = -0.62; 95% CI = -0.93 to -0.31) had the largest effect size in comparison to the studies that used other types of exercise interventions, while both were significant; studies that used FOF as a primary outcome measure (30 studies: SMD = -0.37; 95% CI = -0.52 to -0.22) had a larger effect size than studies that used FOF as a secondary outcome (20 studies: SMD = -0.29; 95% CI = -0.43 to -0.15); and studies that delivered exercise interventions in group settings (30 studies: SMD = 0.38; 95% CI = -0.51 to -0.26) had a larger effect size than studies with individual delivery of exercise interventions (22 studies: SMD = -0.33; 95% CI = -0.52 to -0.14), but both were significant.

Figure 5: Subgroup analyses by outcome measures using post-intervention data

Figure 6: Subgroup analyses by types of exercise interventions using post-intervention data

Figure 7: Subgroup analyses by the duration of intervention using post-intervention data

Figure 8: Subgroup analyses by whether FOF is primary or secondary outcome measures using post-intervention data

Figure 9: Subgroup analyses by whether the intervention was individual or group-based using post-intervention data

4.7.3 Sensitivity Analysis

The effect of study quality was tested. The pooled effect size (SMD = -0.34; 95% CI = -0.44 to -0.23) of 50 studies in which post-intervention values were analyzed decreased to -0.22 (95% CI = -0.36 to -0.8) after removing trials with PEDro Scale scores of <6. The pooled effect size decreased

to -0.25 (95% CI = -0.37 to -0.13) after removing trials with a sample size of <100. However, the results remained significant after the removal of studies with a fair PEDro score or a small sample size.

The influence of using change-from-baseline instead of post-intervention data was also tested in the sensitivity analysis. The meta-analysis of 52 studies using change-from-baseline values (Figure 10) showed that the pooled effect size of exercise interventions on reducing FOF was slightly smaller than the pooled effect size using post-intervention data, but still statistically significant (SMD = -0.28; 95% CI = -0.37 to -0.19).

Figure 10: The pooled effect of exercise interventions on FOF using change-from-baseline values (n=52)

4.7.4 Publication Bias

Visual inspection of the funnel plot (Figure 10) of studies using post-intervention data revealed an asymmetric plot, indicative of the possibility of publication bias.

Figure 11. Funnel plot using post-intervention data

4.8 References

1. Iliffe S, Kendrick D, Morris R, et al. Multicentre cluster randomised trial comparing a community group exercise programme and home-based exercise with usual care for people aged 65 years and over in primary care. *Health Technology Assessment (Winchester, England)*. 2014;18(49):vii-xxvii.
2. Halvarsson A, Franzen E, Faren E, Olsson E, Oddsson L, Stahle A. Long-term effects of new progressive group balance training for elderly people with increased risk of falling: a randomized controlled trial. *Clinical Rehabilitation*. 2012;27(5):450-458.
3. Barnett A, Smith B, Lord SR, Williams M, Baumand A. Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. *Age & Ageing*. 2003;32(4):407-414.
4. Kim S, Lockhart T, Roberto K. The effects of eight-week balance training or weight training: for the elderly on fear of falling measures and social activity levels. *Quality in Ageing*. 2009;10(4):37-48.
5. Shigematsu R, Okura T, Sakai T, Rantanen T. Square-stepping exercise versus strength and balance training for fall risk factors. *Aging Clinical & Experimental Research*. 2008;20(1):19-24.
6. Wolf SL, Barnhart HX, Kutner NG, et al. Selected as the best paper in the 1990s: reducing frailty and falls in older persons: an investigation of tai chi and computerized balance training. *Journal of the American Geriatrics Society*. 2003;51(12):1794-1803.
7. Yamada M, Tanaka B, Nagai K, Aoyama T, Ichihashi N. Rhythmic stepping exercise under cognitive conditions improves fall risk factors in community-dwelling older adults: preliminary results of a cluster-randomized controlled trial. *Aging & Mental Health*. 2011;15(5):647-653.
8. Karinkanta S, Nupponen R, Heinonen A, et al. Effects of exercise on health-related quality of life and fear of falling in home-dwelling older women. *Journal of Aging & Physical Activity*. 2012;20(2):198-214.
9. Lin MR, Wolf SL, Hwang HF, Gong SY, Chen CY. A randomized, controlled trial of fall prevention programs and quality of life in older fallers. *Journal of the American Geriatrics Society*. 2007;55(4):499-506.
10. Wolf B, Feys H, De Weerd W, van der Meer J, Noom M, Aufdemkampe G. Effect of a physical therapeutic intervention for balance problems in the elderly: a single-blind, randomized, controlled multicentre trial. *Clinical Rehabilitation*. 2001;15(6):624-636.
11. Duque G, Boersma D, Loza-Diaz G, et al. Effects of balance training using a virtual-reality system in older fallers. *Clin Interv Aging*. 2013;8:257-263.
12. Li F, Fisher K, Harmer P, McAuley E. Falls self-efficacy as a mediator of fear of falling in an exercise intervention for older adults. *Journals of Gerontology Series B Psychological Sciences & Social Sciences*. 2005;60(1):34-40.
13. Arai T, Obuchi S, Inaba Y, et al. The effects of short-term exercise intervention on falls self-efficacy and the relationship between changes in physical function and falls self-efficacy in Japanese older people: a randomized controlled trial. *American Journal of Physical Medicine & Rehabilitation*. 2007;86(2):133-141.
14. Arantes PM, Dias JMD, Fonseca FF, et al. Effect of a program based on balance exercises on gait, functional mobility, fear of falling, and falls in Pre frail older women. *Topics in Geriatric Rehabilitation*. 2015;31(2):113-120.
15. Arkkukangas M, Johnson ST, Hellström K, Söderlund A, Eriksson S, Johansson A-C. A feasibility study of a randomised controlled trial comparing fall prevention using exercise with or without the support of motivational interviewing. *Preventive Medicine Reports*. 2015;2:134-140.
16. Arkkukangas M, Söderlund A, Eriksson S, Johansson AC. Fall preventive exercise with or without behavior change support for community-dwelling older adults: a randomized controlled trial with short-term follow-up. *J Geriatr Phys Ther*. 2019;42(1):9-17.

17. Bao T, Carender WJ, Kinnaird C, et al. Effects of long-term balance training with vibrotactile sensory augmentation among community-dwelling healthy older adults: a randomized preliminary study. *Journal of Neuroengineering & Rehabilitation*. 2018;15(1):5.
18. Barban F, Annicchiarico R, Melideo M, et al. Reducing fall risk with combined motor and cognitive training in elderly fallers. *Brain Sciences*. 2017;7(2):19.
19. Beyer N, Simonsen L, Bulow J, et al. Old women with a recent fall history show improved muscle strength and function sustained for six months after finishing training. *Aging-Clinical & Experimental Research*. 2007;19(4):300-309.
20. Boongird C, Keesukphan P, Phiphadthakusolkul S, Rattanasiri S, Thakkestian A. Effects of a simple home-based exercise program on fall prevention in older adults: a 12-month primary care setting, randomized controlled trial. *Geriatrics & Gerontology International*. 2017;17(11):2157-2163.
21. Brouwer BJ, Walker C, Rydahl SJ, Culham EG. Reducing fear of falling in seniors through education and activity programs: a randomized trial. *Journal of the American Geriatrics Society*. 2003;51(6):829-834.
22. Campbell AJ, Robertson MC, Gardner MM, Norton RN, Tilyard MW, Buchner DM. Randomised controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. *BMJ*. 1997;315(7115):1065-1069.
23. Clemson L, Singh MAF, Bundy A, et al. Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): randomised parallel trial. *BMJ*. 2012;345.
24. Clemson L, Singh MF, Bundy A, et al. LiFE Pilot Study: A randomised trial of balance and strength training embedded in daily life activity to reduce falls in older adults. *Australian Occupational Therapy Journal*. 2010;57(1):42-50.
25. Cockayne S, Adamson J, Clarke A, et al. Cohort randomised controlled trial of a multifaceted podiatry intervention for the prevention of falls in older people. *PLoS ONE*. 2017;12(1):e0168712.
26. Covill LG, Utley C, Hochstein C. Comparison of Ai Chi and impairment-based aquatic therapy for older adults with balance problems: a clinical study. *Journal of Geriatric Physical Therapy*. 2017;40(4):204-213.
27. Cyarto EV, Brown WJ, Marshall AL, Trost SG. Comparative effects of home- and group-based exercise on balance confidence and balance ability in older adults: cluster randomized trial. *Gerontology*. 2008;54(5):272-280.
28. Devereux K, Robertson D, Briffa NK. Effects of a water-based program on women 65 years and over: a randomised controlled trial. *Australian Journal of Physiotherapy*. 2005;51(2):102-108.
29. Donath L, Faude O, Bridenbaugh SA, et al. Transfer effects of fall training on balance performance and spatiotemporal gait parameters in healthy community-dwelling older adults: a pilot study. *Journal of Aging & Physical Activity*. 2014;22(3):324-333.
30. El-Khoury F, Cassou B, Latouche A, Aegerter P, Charles MA, Dargent-Molina P. Effectiveness of two year balance training programme on prevention of fall induced injuries in at risk women aged 75-85 living in community: Ossebo randomised controlled trial. *BMJ*. 2015;351:h3830.
31. Freiburger E, Blank WA, Salb J, et al. Effects of a complex intervention on fall risk in the general practitioner setting: a cluster randomized controlled trial. *Clinical Interventions in Aging*. 2013;8:1079-1088.
32. Freiburger E, Haberle L, Spirduso WW, Zijlstra GA. Long-term effects of three multicomponent exercise interventions on physical performance and fall-related psychological outcomes in community-dwelling older adults: a randomized controlled trial. *Journal of the American Geriatrics Society*. 2012;60(3):437-446.
33. Gallo E, Stelmach M, Frigeri F, Ahn D-H. Determining whether a dosage-specific and individualized home exercise program with consults reduces fall risk and falls in community-dwelling older adults with difficulty walking: a randomized control trial. *Journal of Geriatric Physical Therapy*. 2018;41(3):161-172.

34. Gine-Garriga M, Guerra M, Unnithan VB. The effect of functional circuit training on self-reported fear of falling and health status in a group of physically frail older individuals: a randomized controlled trial. *Aging-Clinical & Experimental Research*. 2013;25(3):329-336.
35. Gitlin LN, Winter L, Dennis MP, Corcoran M, Schinfeld S, Hauck WW. A randomized trial of a multicomponent home intervention to reduce functional difficulties in older adults. *Journal of the American Geriatrics Society*. 2006;54(5):809-816.
36. Gschwind YJ, Eichberg S, Ejupi A, et al. ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial. *European Review of Aging and Physical Activity*. 2015;12(1):10.
37. Haines TP, Russell T, Brauer SG, et al. Effectiveness of a video-based exercise programme to reduce falls and improve health-related quality of life among older adults discharged from hospital: a pilot randomized controlled trial. *Clinical Rehabilitation*. 2009;23(11):973-985.
38. Halvarsson A, Oddsson L, Olsson E, Faren E, Pettersson A, Stahle A. Effects of new, individually adjusted, progressive balance group training for elderly people with fear of falling and tend to fall: a randomized controlled trial. *Clinical Rehabilitation*. 2011;25(11):1021-1031.
39. Hauer K, Rost B, Rüttschle K, et al. Exercise training for rehabilitation and secondary prevention of falls in geriatric patients with a history of injurious falls. *Journal of the American Geriatrics Society*. 2001;49(1):10-20.
40. Henwood TR, Riek S, Taaffe DR. Strength versus muscle power-specific resistance training in community-dwelling older adults. *Journals of Gerontology Series A-Biological Sciences & Medical Sciences*. 2008;63(1):83-91.
41. Jagdhane S, Kanekar N, Aruin AS. The effect of a four-week balance training program on anticipatory postural adjustments in older adults: a pilot feasibility study. *Current Aging Science*. 2016;9(4):295-300.
42. Jeon MY, Jeong H, Petrofsky J, Lee H, Yim J. Effects of a randomized controlled recurrent fall prevention program on risk factors for falls in frail elderly living at home in rural communities. *Medical Science Monitor*. 2014;20:2283-2291.
43. Josephs S, Pratt ML, Calk Meadows E, Thurmond S, Wagner A. The effectiveness of Pilates on balance and falls in community dwelling older adults. *Journal of Bodywork & Movement Therapies*. 2016;20(4):815-823.
44. Kapan A, Luger E, Haider S, et al. Fear of falling reduced by a lay led home-based program in frail community-dwelling older adults: a randomised controlled trial. *Arch Gerontol Geriatr*. 2017;68:25-32.
45. Kyrдалen IL, Moen K, Røysland AS, Helbostad JL. The Otago exercise program performed as group training versus home training in fall-prone older people: a randomized controlled trial. *Physiotherapy Research International*. 2014;19(2):108-116.
46. Lai C-H, Peng C-W, Chen Y-L, Huang C-P, Hsiao Y-L, Chen S-C. Effects of interactive video-game based system exercise on the balance of the elderly. *Gait & posture*. 2013;37(4):511-515.
47. LaStayo P, Marcus R, Dibble L, Wong B, Pepper G. Eccentric versus traditional resistance exercise for older adult fallers in the community: a randomized trial within a multi-component fall reduction program. *BMC Geriatrics*. 2017;17(1):149.
48. Li F, Harmer P, Fisher KJ, et al. Tai Chi and fall reductions in older adults: a randomized controlled trial. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*. 2005;60(2):187-194.
49. Li F, Harmer P, Chou LS. Dual-Task Walking Capacity Mediates Tai Ji Quan impact on physical and cognitive function. *Med Sci Sports Exerc*. 2019;51(11):2318-2324.
50. Liu H, Rainey J, Zabel R, Quiben MU, Kehayov A, Boswell J. Comparison of two exercise programs using the Falls Efficacy Scale, Berg Balance Scale and ankle dorsiflexor strength in older adults. *Physical & Occupational Therapy in Geriatrics*. 2007;26(2):23-42.
51. Liu YW, Tsui CM. A randomized trial comparing Tai Chi with and without cognitive-behavioral intervention (CBI) to reduce fear of falling in community-dwelling elderly people. *Archives of Gerontology & Geriatrics*. 2014;59(2):317-325.

52. Liu-Ambrose T, Khan KM, Eng JJ, Lord SR, McKay HA. Balance confidence improves with resistance or agility training. Increase is not correlated with objective changes in fall risk and physical abilities. *Gerontology*. 2004;50(6):373-382.
53. Logghe IHJ, Zeeuwe PEM, Verhagen AP, et al. Lack of effect of Tai Chi Chuan in preventing falls in elderly people living at home: a randomized clinical trial. *Journal of the American Geriatrics Society*. 2009;57(1):70-75.
54. McCormack G, Lewin G, McCormack B, Helmes E, Rose E, Naumann F. Pilot study comparing the influence of different types of exercise intervention on the fear of falling in older adults. *Australasian Journal on Ageing*. 2004;23(3):131-135.
55. Oh S, Lim JM, Kim Y, Kim M, Song W, Yoon B. Comparison of the effects of water- and land-based exercises on the physical function and quality of life in community-dwelling elderly people with history of falling: a single-blind, randomized controlled trial. *Archives of Gerontology & Geriatrics*. 2014;60(2):288-293.
56. Okubo Y, Osuka Y, Jung S, et al. Walking can be more effective than balance training in fall prevention among community-dwelling older adults. *Geriatrics & Gerontology International*. 2016;16(1):118-125.
57. Patil R, Karinkanta S, Tokola K, Kannus P, Sievanen H, Uusi-Rasi K. Effects of vitamin D and exercise on the wellbeing of older community-dwelling women: a randomized controlled trial. *Gerontology*. 2016;62(4):401-408.
58. Plummer-D'Amato P, Cohen Z, Dae NA, Lawson SE, Lizotte MR, Padilla A. Effects of once weekly dual-task training in older adults: a pilot randomized controlled trial. *Geriatrics & Gerontology International*. 2012;12(4):622-629.
59. Pollock RD, Martin FC, Newham DJ. Whole-body vibration in addition to strength and balance exercise for falls-related functional mobility of frail older adults: a single-blind randomized controlled trial. *Clinical Rehabilitation*. 2012;26(10):915-923.
60. Roller M, Kachingwe A, Beling J, Ickes DM, Cabot A, Shrier G. Pilates reformer exercises for fall risk reduction in older adults: a randomized controlled trial. *Journal of Bodywork & Movement Therapies*. 2017;22(4):983-998.
61. Sattin RW, Easley KA, Wolf SL, Chen Y, Kutner MH. Reduction in fear of falling through intense tai chi exercise training in older, transitionally frail adults. *Journal of the American Geriatrics Society*. 2005;53(7):1168-1178.
62. Schoene D, Valenzuela T, Toson B, et al. Interactive cognitive-motor step training improves cognitive risk factors of falling in older adults: a randomized controlled trial. *PLoS one*. 2015;10(12):e0145161.
63. Siegrist M, Freiburger E, Geilhof B, et al. Fall prevention in a primary care setting. *Deutsches Arzteblatt International*. 2016;113(21):365-372.
64. Smulders E, Weerdesteyn V, Groen BE, et al. Efficacy of a short multidisciplinary falls prevention program for elderly persons with osteoporosis and a fall history: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*. 2010;91(11):1705-1711.
65. Szturm T, Betker AL, Moussavi Z, Desai A, Goodman V. Effects of an interactive computer game exercise regimen on balance impairment in frail community-dwelling older adults: a randomized controlled trial. *Physical Therapy*. 2011;91(10):1449-1462.
66. Ullmann G, Williams HG, Hussey J, Durstine JL, McClenaghan BA. Effects of Feldenkrais exercises on balance, mobility, balance confidence, and gait performance in community-dwelling adults age 65 and older. *Journal of Alternative & Complementary Medicine*. 2010;16(1):97-105.
67. Vogler CM, Sherrington C, Ogle SJ, Lord SR. Reducing risk of falling in older people discharged from hospital: a randomized controlled trial comparing seated exercises, weight-bearing exercises, and social visits. *Archives of Physical Medicine and Rehabilitation*. 2009;90(8):1317-1324.
68. Voukelatos A, Merom D, Sherrington C, Rissel C, Cumming RG, Lord SR. The impact of a home-based walking programme on falls in older people: the easy steps randomised controlled trial. *Age and Ageing*. 2015;44(3):377-383.

69. Westlake KP, Culham EG. Sensory-specific balance training in older adults: effect on proprioceptive reintegration and cognitive demands. *Physical Therapy*. 2007;87(10):1274-1283.
70. Wetherell JL, Bower ES, Johnson K, Chang DG, Ward SR, Petkus AJ. Integrated exposure therapy and exercise reduces fear of falling and avoidance in older adults: a randomized pilot study. *American Journal of Geriatric Psychiatry*. 2018;26(8):849-859.
71. Wollesen B, Schulz S, Seydell L, Delbaere K. Does dual task training improve walking performance of older adults with concern of falling? *BMC Geriatrics*. 2017;17(1):213.
72. Wu G, Keyes L, Callas P, Ren X, Bookchin B. Comparison of telecommunication, community, and home-based Tai Chi exercise programs on compliance and effectiveness in elders at risk for falls. *Archives of Physical Medicine & Rehabilitation*. 2010;91(6):849-856.
73. Yang XJ, Hill K, Moore K, et al. Effectiveness of a targeted exercise intervention in reversing older people's mild balance dysfunction: a randomized controlled trial. *Physical Therapy*. 2012;92(1):24-37.
74. Yoo EJ, Jun TW, Hawkins SA. The effects of a walking exercise program on fall-related fitness, bone metabolism, and fall-related psychological factors in elderly women. *Research in Sports Medicine*. 2010;18(4):236-250.
75. Zhang L, Weng C, Liu M, Wang Q, Liu L, He Y. Effect of whole-body vibration exercise on mobility, balance ability and general health status in frail elderly patients: a pilot randomized controlled trial. *Clinical Rehabilitation*. 2014;28(1):59-68.
76. Zhao Y, Chung PK, Tong TK. Effectiveness of a community-based exercise program on balance performance and fear of falling in older nonfallers at risk for falling: a randomized, controlled study. *Journal of Aging & Physical Activity*. 2016;24(4):516-524.
77. Higgins JP, Thomas J, Chandler J, et al. *Cochrane Handbook for Systematic Reviews of Interventions*. John Wiley & Sons; 2019.

Chapter 5

Discussion

5.1 Reporting of Principles of Exercise Training and FITT Components

This thesis investigated the extent to which the principles of exercise training and FITT components were reported for FOF exercise interventions in previous RCTs. Among 75 included trials, most of the exercise principles (i.e., overload, reversibility, diminishing return, and initial value) and one of the FITT components (i.e., intensity) were not sufficiently reported, and 63% of the trials reported adherence to exercise interventions. These results resonate with similar work in other populations. A review that assessed the application of exercise principles in people with stroke found that 89.2% of included RCTs reported specificity and 75.7% reported progression, while less than 50% reported on other principles.¹ I will discuss each of the principles in the following sections.

5.1.1 Specificity

The exercise interventions should be designed to be specific for the intended outcomes. In our study, five out of 75 trials did not report sufficient data to comply with the specificity principle. These trials used Tai Chi, video games, walking and whole-body vibration exercises aiming to reduce FOF; however, they did not describe which body systems and muscle groups were targeted to meet the training goals. Without this information, it is difficult to determine the essential ingredients that make interventions effective.

5.1.2 Progression

Twenty-eight percent of the reviewed trials did not report on the principle of progression. This result was similar to another study in which 28% of RCTs did not consider the progression principle in designing breast cancer exercise interventions for women.² The exercise progression of resistance and aerobic exercises was well explained by the physical stress theory of Mueller and Maluf, whereby exercise is prescribed to improve one's physical performance by using mechanical load to trigger

physiological and tissue adaptations.³ When this adaptation accumulates to a certain degree, changes in our body structure and function can be expected. A continuous change of body structure and function relies on a gradual progression of exercise dosage. Sometimes meaningful changes in outcomes cannot be detected if the adaptation stops due to a constant exercise dosage. This theory might explain why some exercise programs that did not apply the principle of progression in our included trials did not find significant outcomes.^{4,5} Finally, the progression in nonconventional exercises such as Tai Chi was less reported than in the resistance and aerobic exercises in our reviewed trials.⁵⁻¹¹ This gap is essential to consider when developing new guidelines for nonconventional exercises, especially on how to progress the exercise.

5.1.3 Overload

A sufficient load is another variable that can cause predictable physiological and tissue adaptations.³ The question is, how much load is enough? Evidence has shown that underloading will not cause predictable adaptations, whereas overloading leads to maladaptation such as tissue injury, fatigue, and loss of exercise motivation.¹² Therefore, applying overload needs to consider the heterogeneity of a participant's baseline capacity. An optimal adaptation occurs when the load is maintained at a level at which it is challenging for the participants. Sixty-nine percent of trials in our study did not report the principle of overload. This gap might be due to the barriers of applying exercise tolerance tests to determine the baseline intensity level for each individual and making a personally tailored plan in group settings.

Despite the inconvenience of implementation of exercise tolerance tests and individually tailored intervention in group settings, it is possible to use a standardized training protocol based on the average baseline test scores while adjusting the training dosage for those individuals with extreme baseline test scores. Furthermore, few included trials in this study reported any maladaptation of exercise training among the participants. Particularly, reporting the dose-provoked side effects in a trial will provide valuable information regarding the maximum exercise load those older adults with FOF can tolerate. A relatively low exercise tolerance might be present among older adults with FOF and fall risks since

balance impairment and sarcopenia are common risk factors for FOF and fall risks. Despite the challenges of applying the overload principle for older adults with FOF, individual-tailored exercise load based on exercise tolerance tests for each type of exercise should be considered in future research that employs exercise interventions.

5.1.4 Initial Value

The initial value was the least reported exercise principle. All trials measured the baseline outcomes, but only four trials compared the training effect between participants with low baseline levels and those with high baseline levels. Reporting the impact of a baseline value on training response can help tailor an exercise program for subgroups of participants with higher or lower functioning levels. Arai et al. found a significant correlation between baseline FES score and the magnitude of change in maximum walking velocity and knee extensor strength in the exercise intervention group.¹³ This finding indicated that combined progressive resistance and balance training was more effective with respect to the physical performance outcomes for the participants with lower FES scores than those with higher scores.¹³

5.1.5 Diminishing Return

Reporting the principle of diminishing return was also infrequent (21% of trials). Knowing when the peak adaptation occurs in participants due to the exercise interventions is an important indicator for the progression of exercise dosage. This principle requires us to continuously monitor the training responses of each individual during the intervention so that adequate doses can be given to maintain the training effect. The pattern of normal training response follows a nonlinear progression. The magnitude of training response can increase exponentially at the early training stage following a period of stagnation. Awareness of this trend helps us develop training strategies to sustain the training benefits. In trials in which the diminishing return principle was applied, key outcomes were measured at least once during the period of intervention.^{6,8,11,14-26} However, none of those trials showed rapid improvement in outcomes at the mid-intervention assessment. An explanation for this result might be the ceiling effect of FOF

outcome measures.^{14,27} It is also possible that many existing FOF measures are not sensitive enough to detect clinically meaningful changes in a short period.²⁸

5.1.6 Reversibility

Sixty-eight percent of trials in this study did not report the exercise principle of reversibility. This principle requires performing at least one follow-up assessment after the intervention is completed. The follow-up assessment is not always a feasible option in research due to time and financial limitations or the burden on the participants. However, the absence of follow-up assessments leads to uncertainty about the retention effect of exercise interventions. Also, when training ceases, a considerable decline of fitness level happens as early as two weeks, and a return to pretraining states appears between ten weeks and eight months.²⁹ Therefore, sustainability should be considered a key component when designing and selecting exercise programs.

5.1.7 FITT Components

The FITT components are the main variables that can be manipulated to follow the exercise principles and generate desired training effects. For example, progression can be applied by increasing either frequency, intensity, or time of exercises. If the FITT components are not reported in detail, it makes it difficult to replicate the exercise interventions in clinical practices to compare the effectiveness of exercise interventions across studies where similar interventions were implemented, and to provide exercise prescription guidelines for older adults suffering from FOF.

Similar to previous literature,^{1,2} intensity was the least reported FITT component in this review. Intensity is a crucial component in the exercise prescription, and it reflects how challenging an exercise task is felt by a participant. Older adults with FOF often have low self-efficacy³⁰, and a person's self-efficacy level is mainly influenced by his/her experience in successfully performing certain tasks such as exercises.³¹ If the intensity of an exercise task is too high, the person might fail to perform the task, leading to a decrease in self-efficacy.

In this study, most trials (44%) used multicomponent exercise interventions (resistance, balance, aerobic etc.), which added complexity to measure the intensity. Additionally, there are well-established

tools that measure participants' intensity levels for endurance and resistance exercises, such as 1RM and maximum rate of oxygen consumption, while there is an absence of validated intensity measures for balance exercises.

One study in this review used the level of difficulty of tasks to quantify the balance exercise intensity.³² Nevertheless, a limitation of using this method is that the challenge of the task cannot be quantified to a level that matches an individual's balance capability. Farlie et al. recently developed the Balance Intensity Scales (BIS) to measure balance intensity relative to the balance capacity of the individual to maintain balance, including a self-rate scale and an objective scale rated by therapists.³³ However, the reliability and validity of the BIS among larger samples of high-intensity tasks and more diverse older adult populations are yet to be tested. Despite the limitations of existing balance intensity measurement tools, researchers are encouraged to use any accessible tools to report balance intensity in their studies or indicate the performance duration of each balance activity until a well-validated instrument is established for measuring balance intensity.

Given that the effectiveness of an exercise intervention relies heavily on participant adherence to the prescribed exercises, it is important to report whether the prescribed exercise dosage was performed. In our study, due to the insufficient report of adherence to exercise dosage, the adherence to program interventions was rated using the percentage or number of total attended exercise sessions. Adherence to exercise dosage refers to the number or percentage of participants who are completely or partially compliant with the prescribed exercise program regarding the frequency, intensity, time, type, and exercise progression. Future research involving exercise interventions is recommended to report adherence to exercise dosage in order to inform clinicians about the proper amount of dosage to retain the acceptability and popularity of different evidence-based exercise programs.

5.2 The Overall Effect of FOF Exercise Intervention

Aligned with previous meta-analyses,³⁴⁻³⁶ results in this study showed an overall small-to-moderate effect size (SMD = -0.34; 95% CI = -0.44 to -0.23) of exercise interventions in reducing FOF. However, the overall effect size of exercise interventions on FOF reduction decreased to -0.22 (95% CI

= -0.36 to -0.8) and to 0.25 (95% CI = -0.37 to -0.13) when studies with only good methodological quality (PEDro Scale score of ≥ 6) and studies with large sample size ($n \geq 100$) were analyzed, respectively. Research shows that RCTs with poor methodological quality and small sample sizes tend to exaggerate or overestimate the effect size.³⁷⁻³⁹ Therefore, we should take the risk of bias into account when interpreting the effect estimate of FOF exercise interventions in this study.

Additionally, a sensitivity analysis using change-from-baseline values to check the robustness of the result in this review showed a slightly decreased overall effect estimate of exercise interventions in reducing FOF (SMD = -0.28; 95% CI = -0.37 to -0.19). This discrepancy might be due to the differences in included studies in each meta-analysis using different approaches.

5.3 Comparing Results with Previous Reviews on FOF Intervention

5.3.1 FOF Exercise Interventions

The effectiveness of exercise interventions in reducing FOF might be explained by Bandura's self-efficacy theory. Mastery experience (successfully performing exercises without falling) are the most valuable source of efficacy information since they provide evidence that an individual can achieve success. This success builds a robust belief in individual's self-efficacy to avoid falling which in turn reduce his/her FOF.

In parallel with the study of Kruisbrink et al.,⁴⁰ this study showed that group-based exercise interventions (SMD = -0.38; 95% CI = -0.51 to -0.26) had a slightly larger effect size than individual-based exercise interventions (SMD = -0.33; 95% CI = -0.52 to -0.14) in reducing FOF. This was also underlined in a previous study, which showed that group exercises have additional psychosocial health benefits through social interaction.⁴¹

In terms of the impact of types of exercise interventions on FOF reduction, the finding of the present study varies from Kruisbrink et al.'s study. In Kruisbrik et al.'s study, researchers examined the pooled effect of all types of interventions in reducing FOF, including exercise interventions across 49 studies and found that 3D exercises (i.e., Tai Chi, yoga, or pilates) had the largest effect size (SMD = -0.823; 95% CI = -1.255 to -0.392).⁴⁰ However, findings in this study showed that balance exercises

yielded the largest effect size (SMD = -0.62; 95% CI = -0.93 to -0.31) among all other types of exercise interventions. This inconsistency might be due to the differences in inclusion criteria since the previous study included a broader range of interventions. Having all FITT components reported in the future will facilitate the comparison of different studies and explain different findings.

Unlike other meta-analyses^{34,35,40} showing that the effect size was not associated with the primary aim of the study, the current meta-analyses revealed that studies with FOF as the primary outcome measure (SMD = -0.37; 95% CI = -0.52 to -0.22) had a larger effect size than those with FOF as secondary outcome measures (SMD = -0.29; 95% CI = -0.43 to -0.15). This finding might reflect the important role of the specificity principle in designing FOF exercise interventions. For instance, an exercise program to treat FOF should explicitly address FOF-related risk factors. If FOF is not the principal outcome expected to be influenced by an exercise program, the effectiveness of the exercise program may be compromised.

5.3.2 Other Types of FOF Interventions

In addition to exercise interventions being effective at reducing FOF among community-dwelling older adults, other types of intervention have been comparatively less researched but may also help reduce FOF. Among them, CBT has recently gained popularity in the field of FOF intervention research due to its direct impact on a person's beliefs and behaviours. Two systematic reviews and meta-analyses by Liu⁴² and Chua⁴³ indicated that the immediate effect size of CBT and CBT-based multi-factorial interventions on FOF reduction were an SMD of 0.25 and -0.28, respectively. The effect sizes of CBT-based interventions in Liu⁴² and Chua's⁴³ studies are smaller than the effects sizes of FOF exercise interventions in this review and Kumar's review.³⁵ Although FOF is a psychological construct, functional impairments are the most common modifiable risk factors for FOF. This might explain how exercise interventions can be more effective in reducing FOF than CBT-based interventions. To illustrate, an indirect effect of exercise interventions may lead to a reduction in FOF and an increase in balance confidence and fall-efficacy via improved dynamic and static balance, functional mobility, and muscle strength.

While exercise interventions appear to be more effective than CBT in reducing FOF immediately after the intervention, the CBT might be a more effective intervention in the long term. Interestingly, the effect sizes of CBT-based interventions in Liu et al.⁴² and Chua et al.'s⁴³ studies increased to an SMD of 0.37 and -0.30 beyond the end of the interventions (6 to 12 months post-intervention). While in Kumar's study,³⁵ the retention effect of exercise interventions in reducing FOF decreased significantly after six months post-intervention. This might be explained by the reversibility effect of exercise training on individuals' physiological adaptations, which might also impact their psychological adaptations. Once the physiological adaptations stop and return to the original level, individuals' belief in their ability to avoid falls and maintain balance will also gradually return to the baseline level.

CBT might be effective in tackling FOF for older adults who have FOF without actual functional impairments, but CBT intervention alone might not be sufficient to target older adults who are both fearful about falling and have actual functional impairments such as poor balance and sarcopenia. That is why many current CBT-based interventions were integrated with exercises, as demonstrated in a recent review.⁴³ Therefore, an ideal FOF intervention might be a combination of these two approaches.

Some fall prevention programs that attempted to address risk factors of falling also showed effectiveness in reducing FOF. For example, evidence from a systematic review by Sjosten and colleagues seems to support the benefits of multifactorial fall-prevention programs and Tai Chi as a single-component fall-prevention program for FOF.⁴⁴ Yoshikawa et al.'s meta-analysis also showed that the effect size of A Matter of Balance Volunteer Lay Leader (AMOB/ALL) model fall-prevention program on FOF measured by affective construct was an SMD of -0.29 (9 studies, CI: -0.4, -0.19) and on FOF measured by cognitive construct was SMD of 0.51 (10 studies, CI: 0.42, 0.60).³⁶ These effect estimates were comparable with those in the present study. However, their findings should be interpreted with extra caution, given that most of the included studies in their review were a quasi-experimental design which might overestimate the program effects.

FOF and falls share many overlapping risk factors, so fall prevention programs might be able to reduce FOF by managing those shared risk factors.⁴⁵ However, an exercise program should be targeted to

a specific group of people likely to benefit most from the intervention.⁴⁶ Fall prevention programs may not be specific enough for older adults who experience FOF without having actual fall risks.

Consequently, we should distinguish older adults with actual fall risks from those with FOF only when planning a fall prevention program in a community to prevent wasting resources.

5.4 Implications for Future Research, Practice and Policy

5.4.1 Research Implications

Researchers in current FOF exercise intervention research have not paid sufficient attention to reporting measures of exercise prescription. Particularly, principles of exercise training including overload, initial value, reversibility and diminishing return, and intensity in FITT components were reported in less than 50% of the included trials. This insufficient reporting of measures of exercise prescription might be a barrier to research reproduction and knowledge mobilization. To address this gap, future research involving exercise interventions should report the application of exercise principles and FITT components more transparently. The Consensus on Exercise Reporting Template (CERT) is a good tool to help researchers document the essential components of exercise intervention in various study designs.⁴⁷

Given the critical role of balance exercise in addressing the issue of FOF in older adults, there is a need for the establishment of reliable instruments to measure the intensity of balance exercises. More studies should focus on testing the dose-response effect of exercise interventions to identify the minimum doses required for effective interventions to address FOF. Furthermore, most trials in this study were focused on the causal effect of an exercise intervention on FOF alleviation, but little is known about the underlying mechanisms. Therefore, more research needs to explore the interaction between exercise dosage, physical performance, and FOF reduction. Given the significant long-term effect of CBT-based intervention, researchers should expand studies comparing the effects of CBT intervention alone on FOF reduction among older adults with a high level of functional impairment to the effects on older adults with a low level of functional impairment. Finally, to prolong the benefits of exercise interventions,

researchers should develop more sustainable exercise programs, meaning that participants should be given adequate support to continue the exercise programs after the end of the interventions.

5.4.2 Practice Implications

This study showed that exercise interventions in previous RCTs that used balance exercises or were implemented in group settings have larger effect sizes than other types or one-to-one exercises. Regarding the dose of FOF exercises, most of the interventions with significant effects on FOF reduction used a frequency ≥ 3 times per week for at least 12 weeks, a duration ≥ 30 minutes for each session, and moderate-intensity (RPE from 12 to 13, HRmax from 64% to 76%, 1RM from 60% to 70%). Therefore, balance exercise or integrating a balance component into an exercise program should be emphasized for older adults who are at risk of FOF. Finally, any exercise program at moderate intensity at least three times per week for 30 minutes each time is recommended for community-dwelling older adults with FOF.

5.4.3 Policy Implication

In light of the high prevalence and adverse impact of FOF in community-dwelling older adults, policymakers should emphasize the FOF issue by supporting screening tools, identifying patients at risk of FOF and providing resources to develop effective interventions to cope with FOF. First, general physicians are uniquely positioned to identify older adults at risk of FOF and facilitate exercise participation. It has been reported that older adults who receive advice and support about physical activity from their physicians are more likely to participate in a regular physical activity program.⁴⁸ To raise awareness of the FOF issue in older adults, an educational brochure that provides an overview of concepts, risk factors, consequences, and recommended interventions of FOF can be distributed to general physicians as well as other healthcare providers. Secondly, simple assessment tools such as FES-I, ABC, SAFE, or single-item questions can be used to identify older adults likely to benefit from an exercise program aimed at reducing FOF in primary care settings. Finally, an exercise program with an emphasis on the balance component and proper dosage that is implemented in a community group setting can be an effective intervention to reduce FOF and improve physical function for older adults. To this end, grant

funding should be made available to create a community-based exercise program specifically to address FOF.

5.5 Strengths and Limitations

This study included 75 RCTs in the qualitative review and 50 RCTs in the meta-analysis. It is the largest and the first comprehensive overview to date of the effect of exercise interventions on reducing FOF based on the exercise principles and FITT components. To reduce the risk of publication bias, a comprehensive searching strategy was established with the assistance of a health science librarian, and a wide range of databases was searched without restricting publication dates and languages. Ensuring a rigorous systematic review, the PRISMA and AMSTAR2 checklists and Cochrane guidelines were followed when conducting and reporting this study. Two reviewers conducted a pilot test of data-extracting sheets independently to ensure systematic data collection. This study considered the impact of a sample size of the included RCTs, the methodological quality of the trials and the use of a different data set (change-from-baseline values) when estimating the effect of exercise interventions in FOF reduction. With subgroup analyses, this study helped gain insight into the effectiveness of FOF exercise interventions regarding the characteristics of exercise prescription.

However, this study includes several possible limitations. In particular, the exclusion of trials focusing on condition-specific clinical populations such as participants with stroke and long-term care residents has limited the generalizability to all older adults with FOF. Furthermore, due to the discrepancies of follow-up reports after exercise interventions in reviewed studies, the long-term effects of FOF exercise interventions were not investigated in this study. Additionally, concrete evidence on how variables related to exercise prescriptions such as intensity and supervised or non-supervised delivery of exercises impact the effectiveness of FOF exercise interventions is yet to be clarified. The inadequate reports of exercise principles and parameters undermine efforts to thoroughly examine the optimal dosage and progression for FOF exercise prescription. Trials included in this study also showed a high risk of performance bias since no trials masked participants and therapists. However, it should be noted that masking participants and therapists for exercise interventions is extremely difficult in such studies.

5.6 Conclusion

Previous RCTs did not fully and consistently report the measures of exercise prescriptions. In the reviewed trials, most principles of exercise training (overload, initial values, reversibility, and diminishing return) and intensity in FITT components were not sufficiently reported. Exercise interventions in previous RCTs had an overall small-to-moderate effect size on reducing FOF in community-dwelling older adults, and balance exercise had the largest effect size of all types of exercise interventions (i.e., multi-component, resistance, aerobic, 3D and novel exercises). Furthermore, although most of the trials had good methodological quality, the risks of performance, detection and selection biases were relatively high across trials. Future research should provide a more comprehensive reporting of the exercise principles and FITT components to translate robust research findings into clinical practice. The present author recommends that community-dwelling older adults with FOF participate in moderate-intensity group exercise programs with a balance exercise component at least three times per week for 30 minutes in each session. Authorities should make these programs available for older adults at risk of FOF.

5.7 References

1. Ammann BC, Knols RH, Baschung P, De Bie RA, de Bruin ED. Application of principles of exercise training in sub-acute and chronic stroke survivors: a systematic review. *BMC Neurology*. 2014;14(1):167.
2. Neil-Sztramko SE, Winters-Stone KM, Bland KA, Campbell KL. Updated systematic review of exercise studies in breast cancer survivors: attention to the principles of exercise training. *British Journal of Sports Medicine*. 2019;53(8):504.
3. Mueller MJ, Maluf KS. Tissue adaptation to physical stress: a proposed “physical stress theory” to guide physical therapist practice, education, and research. *Physical Therapy*. 2002;82(4):383-403.
4. Devereux K, Robertson D, Briffa NK. Effects of a water-based program on women 65 years and over: a randomised controlled trial. *Australian Journal of Physiotherapy*. 2005;51(2):102-108.
5. Logghe IHJ, Zeeuwe PEM, Verhagen AP, et al. Lack of effect of Tai Chi Chuan in preventing falls in elderly people living at home: a randomized clinical trial. *Journal of the American Geriatrics Society*. 2009;57(1):70-75.
6. Li F, Fisher K, Harmer P, McAuley E. Falls self-efficacy as a mediator of fear of falling in an exercise intervention for older adults. *Journals of Gerontology Series B Psychological Sciences & Social Sciences*. 2005;60(1):34-40.
7. Li F, Harmer P, Chou LS. Dual-task walking capacity mediates Tai Ji Quan impact on physical and cognitive function. *Medicine and Science in Sports and Exercise*. 2019;51(11):2318-2324.
8. Li F, Harmer P, Fisher KJ, et al. Tai Chi and fall reductions in older adults: a randomized controlled trial. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*. 2005;60(2):187-194.
9. Liu YW, Tsui CM. A randomized trial comparing Tai Chi with and without cognitive-behavioral intervention (CBI) to reduce fear of falling in community-dwelling elderly people. *Archives of Gerontology & Geriatrics*. 2014;59(2):317-325.
10. Wu G, Keyes L, Callas P, Ren X, Bookchin B. Comparison of telecommunication, community, and home-based Tai Chi exercise programs on compliance and effectiveness in elders at risk for falls. *Archives of Physical Medicine & Rehabilitation*. 2010;91(6):849-856.
11. Sattin RW, Easley KA, Wolf SL, Chen Y, Kutner MH. Reduction in fear of falling through intense tai chi exercise training in older, transitionally frail adults. *Journal of the American Geriatrics Society*. 2005;53(7):1168-1178.
12. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. Lippincott Williams & Wilkins; 2013.
13. Arai T, Obuchi S, Inaba Y, et al. The effects of short-term exercise intervention on falls self-efficacy and the relationship between changes in physical function and falls self-efficacy in Japanese older people: a randomized controlled trial. *American Journal of Physical Medicine & Rehabilitation*. 2007;86(2):133-141.
14. Bao T, Carender WJ, Kinnaird C, et al. Effects of long-term balance training with vibrotactile sensory augmentation among community-dwelling healthy older adults: a randomized preliminary study. *Journal of Neuroengineering & Rehabilitation*. 2018;15(1):5.
15. Barban F, Annicchiarico R, Melideo M, et al. Reducing fall risk with combined motor and cognitive training in elderly fallers. *Brain Sciences*. 2017;7(2):19.
16. Boongird C, Keesukphan P, Phiphadthakusolkul S, Rattanasiri S, Thakkinstian A. Effects of a simple home-based exercise program on fall prevention in older adults: a

- 12-month primary care setting, randomized controlled trial. *Geriatrics & Gerontology International*. 2017;17(11):2157-2163.
17. Clemson L, Singh MF, Bundy A, et al. LiFE pilot study: a randomised trial of balance and strength training embedded in daily life activity to reduce falls in older adults. *Australian Occupational Therapy Journal*. 2010;57(1):42-50.
 18. Freiburger E, Haberle L, Spirduso WW, Zijlstra GA. Long-term effects of three multicomponent exercise interventions on physical performance and fall-related psychological outcomes in community-dwelling older adults: a randomized controlled trial. *Journal of the American Geriatrics Society*. 2012;60(3):437-446.
 19. Gallo E, Stelmach M, Frigeri F, Ahn D-H. Determining whether a dosage-specific and individualized Home Exercise Program with consults reduces fall risk and falls in community-dwelling older adults with difficulty walking: a randomized control trial. *Journal of Geriatric Physical Therapy*. 2018;41(3):161-172.
 20. Haines TP, Russell T, Brauer SG, et al. Effectiveness of a video-based exercise programme to reduce falls and improve health-related quality of life among older adults discharged from hospital: a pilot randomized controlled trial. *Clinical Rehabilitation*. 2009;23(11):973-985.
 21. Henwood TR, Riek S, Taaffe DR. Strength versus muscle power-specific resistance training in community-dwelling older adults. *Journals of Gerontology Series A-Biological Sciences & Medical Sciences*. 2008;63(1):83-91.
 22. Patil R, Karinkanta S, Tokola K, Kannus P, Sievanen H, Uusi-Rasi K. Effects of vitamin D and exercise on the wellbeing of older community-dwelling women: a randomized controlled trial. *Gerontology*. 2016;62(4):401-408.
 23. Roller M, Kachingwe A, Beling J, Ickes DM, Cabot A, Shrier G. Pilates reformer exercises for fall risk reduction in older adults: a randomized controlled trial. *Journal of Bodywork & Movement Therapies*. 2017;22(4):983-998.
 24. Wetherell JL, Bower ES, Johnson K, Chang DG, Ward SR, Petkus AJ. Integrated exposure therapy and exercise reduces fear of falling and avoidance in older adults: a randomized pilot study. *American Journal of Geriatric Psychiatry*. 2018;26(8):849-859.
 25. Zhang L, Weng C, Liu M, Wang Q, Liu L, He Y. Effect of whole-body vibration exercise on mobility, balance ability and general health status in frail elderly patients: a pilot randomized controlled trial. *Clinical Rehabilitation*. 2014;28(1):59-68.
 26. Zhao Y, Chung PK, Tong TK. Effectiveness of a community-based exercise program on balance performance and fear of falling in older nonfallers at risk for falling: a randomized, controlled study. *Journal of Aging & Physical Activity*. 2016;24(4):516-524.
 27. McCormack G, Lewin G, McCormack B, Helmes E, Rose E, Naumann F. Pilot study comparing the influence of different types of exercise intervention on the fear of falling in older adults. *Australasian Journal on Ageing*. 2004;23(3):131-135.
 28. Jørstad EC, Hauer K, Becker C, Lamb SE, Group obotP. Measuring the psychological outcomes of falling: a systematic review. *Journal of the American Geriatrics Society*. 2005;53(3):501-510.
 29. Rivera-Brown AM, Frontera WR. Principles of exercise physiology: responses to acute exercise and long-term adaptations to training. *Pm&r*. 2012;4(11):797-804.
 30. Denking MD, Lukas A, Nikolaus T, Hauer K. Factors associated with fear of falling and associated activity restriction in community-dwelling older adults: a systematic review. *The American Journal of Geriatric Psychiatry*. 2015;23(1):72-86.
 31. McAuley E, Mihalko SL, Rosengren K. Self-efficacy and balance correlates of fear of falling in the elderly. *Journal of Aging and Physical Activity*. 1997;5(4):329-340.

32. Duque G, Boersma D, Loza-Diaz G, et al. Effects of balance training using a virtual-reality system in older fallers. *Clinical Interventions in Aging*. 2013;8:257-263.
33. Farlie MK, Keating JL, Molloy E, et al. The Balance Intensity Scales for therapists and exercisers measure balance exercise intensity in older adults: initial validation using Rasch analysis. *Physical Therapy*. 2019;99(10):1394-1404.
34. Kendrick D, Kumar A, Carpenter H, et al. Exercise for reducing fear of falling in older people living in the community. *Cochrane Library*. 2014;2015(11):CD009848-CD009848.
35. Kumar A, Delbaere K, Zijlstra G, et al. Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and Ageing*. 2016;45(3):345-352.
36. Yoshikawa A, Ramirez G, Smith ML, Lee S, Ory MG. Systematic review and meta-analysis of fear of falling and fall-related efficacy in a widely disseminated community-based fall prevention program. *Archives of Gerontology and Geriatrics*. 2020;91:104235.
37. Dechartres A, Trinquart L, Boutron I, Ravaud P. Influence of trial sample size on treatment effect estimates: meta-epidemiological study. *BMJ*. 2013;346.
38. Zlowodzki M, Poolman RW, Kerkhoffs GM, Tornetta III P, Bhandari M, Group IE-BOSW. How to interpret a meta-analysis and judge its value as a guide for clinical practice. *Acta Orthopaedica*. 2007;78(5):598-609.
39. Savović J, Jones HE, Altman DG, et al. Influence of reported study design characteristics on intervention effect estimates from randomized, controlled trials. *Annals of Internal Medicine*. 2012;157(6):429-438.
40. Kruisbrink M, Delbaere K, Kempen GI, et al. Intervention characteristics associated with a reduction in fear of falling among community-dwelling older people: a systematic review and meta-analysis of randomized controlled trials. *The Gerontologist*. 2020.
41. Hayashi T, Kondo K, Kanamori S, et al. Differences in falls between older adult participants in group exercise and those who exercise alone: a cross-sectional study using Japan Gerontological Evaluation Study (JAGES) data. *International Journal of Environmental Research and Public Health*. 2018;15(7):1413.
42. Liu T-W, Ng GY, Chung RC, Ng SS. Cognitive behavioural therapy for fear of falling and balance among older people: a systematic review and meta-analysis. *Age and Ageing*. 2018;47(4):520-527.
43. Chua CHM, Jiang Y, Lim DS, Wu VX, Wang W. Effectiveness of cognitive behaviour therapy-based multicomponent interventions on fear of falling among community-dwelling older adults: a systematic review and meta-analysis. *Journal of Advanced Nursing*. 2019;75(12):3299-3315.
44. Sjösten N, Vaapio S, Kivelä S-L. The effects of fall prevention trials on depressive symptoms and fear of falling among the aged: a systematic review. *Aging and Mental Health*. 2008;12(1):30-46.
45. Young WR, Williams AM. How fear of falling can increase fall-risk in older adults: applying psychological theory to practical observations. *Gait & Posture*. 2015;41(1):7-12.
46. Barnett A, Smith B, Lord SR, Williams M, Baumann A. Community-based group exercise improves balance and reduces falls in at-risk older people: a randomised controlled trial. *Age & Ageing*. 2003;32(4):407-414.
47. Slade SC, Dionne CE, Underwood M, Buchbinder R. Consensus on Exercise Reporting Template (CERT): explanation and elaboration statement. *British Journal of Sports Medicine*. 2016;50(23):1428-1437.

48. Booth ML, Bauman A, Owen N, Gore CJ. Physical activity preferences, preferred sources of assistance, and perceived barriers to increased activity among physically inactive Australians. *Preventive Medicine*. 1997;26(1):131-137.

Appendix A Search History from EMBASE

EMBASE		
#	Searches	Results
1	Fear/	30559
2	exp Psychological Trauma/	962
3	Resilience, Psychological/	5016
4	exp Accidental Falls/	22988
5	or/1-3	36412
6	4 and 5	761
7	exp Exercise/ or exp Exercise Therapy/	215658
8	train*. mp.	537699
9	7 or 8	700952
10	6 and 9	216
11	exp Randomized Controlled Trials as Topic/ or exp Clinical Trials as Topic/ or Treatment Outcome/	1286713
12	exp Humans/	18104851
13	11 or 12	18139621
14	10 and 13	216
15	limit 14 to "all aged (65 and over)"	196

Appendix B Search History from PsycINFO

PsycINFO		
#	Searches	Results
1	falls/	22988
2	Fear/	30559
3	1 and 2	759
4	exp Exercise/	185066
5	exp Exercise Therapy/	47935
6	4 or 5	215658
7	3 and 6	189
8	exp Randomized Controlled Trials as Topic/	131605
9	exp controlled clinical trial/	583362
10	8 or 9	707209
11	7 and 10	69

Appendix C Search History from Medline

Medline		
#	Searches	Results
1	(fear adj5 fall*).mp.	1702
2	(concern* adj5 fall*).mp.	645
3	(afraid adj5 fall*).mp.	55
4	(psychol* adj5 fall*).mp.	255
5	(self efficacy adj5 fall*).mp	215
6	(balance adj5 confiden*).mp.	966
7	or/1-6	3364
8	exercis*.mp	366553
9	training.mp.	417366
10	exp exercise therapy/ or endurance training/ or motion therapy, continuous passive/or muscle stretching exercises/ or plyometric exercise/ or resistance training/	47935
11	exp exercise/or muscle stretching exercises/	185066
12	or/8-11	762913
13	exp Nervous System Diseases/	2438570
14	exp Musculoskeletal Diseases/	1056304
15	13 or 14	3273144
16	7 and 12	1160
17	16 not 15	776
18	exp controlled clinical trial/or exp randomized controlled trial/	583362
19	17 and 18	195

Appendix D Search History from CINAHL

CINAHL				
#	Query	Limiters/Expanders	Last Run Via	Results
S5	S3 AND S4	Expanders - Apply related words; Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	122
S4	(MH "Therapeutic Exercise+")	Expanders - Apply related words; Apply equivalent subjects Search Boolean/Phrase modes -	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	47,762
S3	S1 OR S2	Expanders - Apply related words; Apply equivalent subjects Search Boolean/Phrase modes - equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,296
S2	(MH "Accidental Falls/PF")	Expanders - Apply related words; Apply equivalent subjects Search Boolean/Phrase modes - equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	338
S1	"fear of fall*"	Expanders - Apply related words; Apply equivalent subjects Search modes - Boolean/Phrase	Interface - EBSCOhost Research Databases Search Screen - Advanced Search Database - CINAHL	1,141

Appendix E Excluded Studies and Reasons for Exclusion

Author	Year	Title	reasons
Clemson, L	2004	The Effectiveness of a Community-Based Program for Reducing the Incidence of Falls in the Elderly: A Randomized Trial	Multi-component intervention
Gawler, S	2016	Reducing falls among older people in general practice: The ProAct65+ exercise intervention trial	Identical data source
Gitlin, L	2008	Variation in response to a home intervention to support daily function by age, race, sex, and education	non-RCT
Hinman	2002	Comparison of Two Short-term Balance Training Programs for Community-dwelling Older Adults	age<65
Lajoie, Y.	2004	Effect of computerized feedback postural training on posture and attentional demands in older adults	non-RCT
Lin, M. R.	2006	Community-based tai chi and its effect on injurious falls, balance, gait, and fear of falling in older people	non-RCT
Montero-Alía, P	2019	Controlled trial of balance training using a video game console in community-dwelling older adults	non-RCT
Nguyen, M	2012	A randomized controlled trial of Tai chi for balance, sleep quality and cognitive performance in elderly Vietnamese	age<65
Pirauá, A	2019	Effect of 24-week strength training on unstable surfaces on mobility, balance, and concern about falling in older adults	age<65
Reinsch, S.	1992	Attempts to prevent falls and injury: a prospective community study	age<65
Rendon, A. A.	2012	The effect of virtual reality gaming on dynamic balance in older adults	age<65
Resnick, B.	2008	Testing the Senior Exercise Self-efficacy Project (SESEP) for use with urban dwelling minority older adults	non-exercise intervention
Robertson, M. C.	2001	Effectiveness and economic evaluation of a nurse delivered home exercise programme to prevent falls. 1: Randomised controlled trial	no FOF outcome measures
Sihvonen, S.	2004	Fall incidence in frail older women after individualized visual feedback-based balance training	Participants were institutionalized
Sihvonen, S. E.	2004	Changes in postural balance in frail elderly women during a 4-week visual feedback training: a randomized controlled trial	Participants were institutionalized

Author	Year	Title	reasons
Tiedemann, A.	2013	A 12-week Iyengar yoga program improved balance and mobility in older community-dwelling people: a pilot randomized controlled trial	age<65
Tiedemann, A.	2012	Can yoga improve balance in older people?: A randomised controlled trial	age<65
Tinetti, M	1994	A multifactorial intervention to reduce the risk of falling among elderly people living in the community	non-RCT
Vind, A	2010	Effect of a program of multifactorial fall prevention on health-related quality of life, functional ability, fear of falling and psychological well-being. A randomized controlled trial	Multi-component intervention
Vrantsidis, F.	2009	Getting Grounded Gracefully: effectiveness and acceptability of Feldenkrais in improving balance	age<65
Wallsten, S	2006	The Effect of Tai Chi Chuan on Confidence and Lower Extremity Strength and Balance in Residents Living Independently at a Continuing Care Retirement Community	age<65
Weerdesteyn, V.	2006	A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly	non-RCT
Yates, S	2001	Evaluating the effectiveness of a home-based fall risk reduction program for rural community-dwelling older adults	Non-exercise intervention
Lin, M. R.	2006	Community-based tai chi and its effect on injurious falls, balance, gait, and fear of falling in older people	non-RCT
Reinsch, S.	1992	Attempts to prevent falls and injury: a prospective community study	age<65
Zhang, J. G.	2006	The effects of Tai Chi Chuan on physiological function and fear of falling in the less robust elderly: an intervention study for preventing falls	age<65
Donat, H.	2007	Comparison of the effectiveness of two programmes on older adults at risk of falling: unsupervised home exercise and supervised group exercise	Participants were institutionalized
Frandin, K.	2009	A Nordic multi-center study on physical and daily activities for residents in nursing home settings: design of a randomized, controlled trial	Participants were institutionalized
Frandin, K.	2016	Long-Term Effects of Individually Tailored Physical Training and Activity on Physical Function, Well-Being and Cognition in Scandinavian Nursing Home Residents: A Randomized Controlled Trial	Participants were institutionalized
Furtado, G	2016	Effects of a chair-yoga exercises on stress hormone levels, daily life activities, falls and physical fitness in institutionalized older adults	Participants were institutionalized

Author	Year	Title	reasons
Gusi, N.	2012	Balance training reduces fear of falling and improves dynamic balance and isometric strength in institutionalised older people: a randomised trial	Participants were institutionalized
Hauer, K.	2003	Two years later: a prospective long-term follow-up of a training intervention in geriatric patients with a history of severe falls	Participants were institutionalized
Halvarsson, A	2012	Long-term effects of new progressive group balance training for elderly people with increased risk of falling - a randomized controlled trial	Identical data source
Hewitt, J	2018	Progressive Resistance and Balance Training for Falls Prevention in Long-Term Residential Aged Care: A Cluster Randomized Trial of the Sunbeam Program	Participants were institutionalized
Hewitt, J.	2014	Does progressive resistance and balance exercise reduce falls in residential aged care? Randomized controlled trial protocol for the SUNBEAM program	Participants were institutionalized
Huang, T	2016	Evaluation of a combined cognitive-behavioural and exercise intervention to manage fear of falling among elderly residents in nursing homes	Participants were institutionalized
Rossano, C	2016	Visually- guided gait training in paretic patients during the first rehabilitation phase: study protocol for a randomized controlled trial	Participants were institutionalized
Sanchez - Padilla, M	2016	Effectiveness of a Proprioceptive Exercise Program in Nursing Home Residents	Participants were institutionalized
Schoenfelder, D. P	2000	A fall prevention program for elderly individuals. Exercise in long-term care settings	Participants were institutionalized
Schoenfelder, D. P.	2004	An exercise program to improve fall-related outcomes in elderly nursing home residents	Participants were institutionalized
Tousignant, M.	2012	The effect of supervised Tai Chi intervention compared to a physiotherapy program on fall-related clinical outcomes: a randomized clinical trial	Participants were institutionalized
Underwood, M.	2011	The OPERA trial: protocol for a randomised trial of an exercise intervention for older people in residential and nursing accommodation	Participants were institutionalized

Author	Year	Title	reasons
Aibar-Almazán, A	2019	Effects of Pilates on fall risk factors in community-dwelling elderly women: A randomized, controlled trial	age<65
Azizan, A	2015	Elders' Exercise and Behavioral Program: Effects on Balance and Fear of Falls	age<65
Beauvais, A	2014	Reducing the Fear of Falling Through a Community Evidence-Based Intervention	non-RCT
Boon Chong, K	2016	Effects of Wii Active exercises on fear of falling and functional outcomes in community-dwelling older adults: a randomised control trial	age<65
Britten, L	2017	Dancing in time: feasibility and acceptability of a contemporary dance programme to modify risk factors for falling in community dwelling older adults	age<65
Brovold, T.	2012	The efficacy of counseling and progressive resistance home-exercises on adherence, health-related quality of life and function after discharge from a geriatric day-hospital	age<65
Chen, J	2018	The Effects of Tae Kwon Do-Based Exercise vs. Standard Balance Exercises on Fall Risk in Older Adults	non-RCT
de, Carvalho Fonseca	2018	Effect of the Auricular Acupoint Associated with Physical Exercise in Elderly People: A Randomized Clinical Test	age<65
Delbaere, K	2006	A home-based multidimensional exercise program reduced physical impairment and fear of falling	non-RCT
Gomes, G. C. V.	2018	Feasibility, safety, acceptability, and functional outcomes of playing Nintendo Wii Fit Plus™ for frail older adults: A randomized feasibility clinical trial	age<65
Halvarsson, A	2015	Taking balance training for older adults one step further: the rationale for and a description of a proven balance training programme	non-RCT
Hamrick, I.	2017	Yoga's effect on falls in rural, older adults	age<65
Hita-Contreras F	2016	Fall prevention in postmenopausal women: the role of Pilates exercise training	non-RCT
Huang, T. T.	2011	Reducing the fear of falling among community-dwelling elderly adults through cognitive-behavioural strategies and intense Tai Chi exercise: a randomized controlled trial	age<65
Iliffe, S	2015	Promoting physical activity in older people in general practice: ProAct65+ cluster randomised controlled trial	
Kuo, S. L.	2011	Effect of exercise intervention on balance and fear of falling in elderly subjects	non-RCT

Author	Year	Title	reasons
Kwok, B. C.	2016	Effects of WiiActive exercises on fear of falling and functional outcomes in community-dwelling older adults: a randomised control trial	age<65
Kwon, M. S.	2011	[Effects of a fall prevention program on physical fitness and psychological functions in community dwelling elders]	non-RCT
Lin, M. R.	2006	Community-based tai chi and its effect on injurious falls, balance, gait, and fear of falling in older people	non-RCT
Mihay, L. M.	2006	The effect of Tai Chi inspired exercise compared to strength training: a pilot study	non-RCT
Padala, Kalpana P.	2017	Efficacy of Wii-Fit on Static and Dynamic Balance in Community Dwelling Older Veterans: A Randomized Controlled Pilot Trial	age<65
Pata, Rachel W.	2014	e effect of Pilates based exercise on mobility, postural stability, and balance in order to decrease fall risk in older adults	age<65
Prata, Melina Galleti	2015	Effects of strength and balance training on the mobility, fear of falling and grip strength of elderly female fallers	age<65
Robinson, James B.	2018	An Interdisciplinary Intervention for Fear of Falling: Lessons Learned from Two Case Studies	non-RCT
Sá, César	2019	Results of an Aquatic Exercise Program on Balance, Risk of Falls, Fear of Falling, and Quality of Life in Older Adults	age<65
Sales, M.	2017	A Novel Exercise Initiative for Seniors to Improve Balance and Physical Function	age<65
Schilling, B. K.	2009	Effects of unstable surface training on measures of balance in older adults	age<65
Schwarting, A. E.	2002	The effectiveness of an intervention plan in decreasing fear of falling	non-RCT
Singh, D. K.	2012	Participating in a virtual reality balance exercise program can reduce risk and fear of falls	age<65
Skinner, Elizabeth H.	2016	An Ai Chi-based aquatic group improves balance and reduces falls in community-dwelling adults: A pilot observational cohort study	non-RCT
Taggart, Hm	2002	Effects of Tai Chi exercise on balance, functional mobility, and fear of falling among older women	non-RCT
Takai, I	2010	[Influence of balance exercises during an attention task on fear of falling among frail elderly fallen]. [Japanese]	Participants were institutionalized

Author	Year	Title	reasons
Tisher, K.	2019	Functional measures show improvements after a home exercise program following supervised balance training in older adults with elevated fall risk	age<65
Toronjo-Hornillo, L	2018	Effects of the Application of a Program of Adapted Utilitarian Judo (JUA) on the Fear of Falling Syndrome (FOF) for the Health Sustainability of the Elderly Population	non-RCT
Wetherell, JI	2016	Activity, balance, learning, and exposure (ABLE): a new intervention for fear of falling	non-RCT
Wu, G	2006	Group tele-exercise for improving balance in elders	non-RCT
Yan, T.	2009	Results from the Healthy Moves for Aging Well program: changes of the health outcomes	non-RCT
Yang, F	2015	Controlled whole-body vibration training reduces risk of falls among community-dwelling older adults	non-RCT
Yeung, Py	2015	A community-based Falls Management Exercise Programme (FaME) improves balance, walking speed and reduced fear of falling	age<65
Yoo, J. S.	2013	Effects of a Fall Prevention Program on Falls in Frail Elders Living at Home in Rural Communities	non-RCT
Zhang, J. G.	2006	The effects of Tai Chi Chuan on physiological function and fear of falling in the less robust elderly: an intervention study for preventing falls	age<65

Appendix F Subgroup Analyses for Studies Using Change-from-baseline Values

Subgroups by outcome measures

Subgroups by type of exercise

Subgroups by duration of intervention

Subgroups by primary or secondary outcome measures

Subgroups by individual or group-based exercise

Appendix G PRISMA Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Cover page
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page ii
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 13-19
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 19-20
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 47-48
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 47
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 47
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 47-51
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 47-51
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 48
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 48-52
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 50-51
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 51-52
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 48-50

Section and Topic	Item #	Checklist item	Location where item is reported
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 51-52
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 51
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 51-52
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 51-52
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 52
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 52
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 52
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 55
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 55
Study characteristics	17	Cite each included study and present its characteristics.	Page 58-65
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 67-72
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Page 87
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 87-95
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 87-95
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 87-95
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 93-95
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 95

Section and Topic	Item #	Checklist item	Location where item is reported
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 87-94
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 101, 105-108
	23b	Discuss any limitations of the evidence included in the review.	Page 110-111
	23c	Discuss any limitations of the review processes used.	Page 110-111
	23d	Discuss implications of the results for practice, policy, and future research.	Page 109-110
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	N/A
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	N/A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	N/A
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	N/A
Competing interests	26	Declare any competing interests of review authors.	Page 111
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 115-137

Appendix H AMSTAR2

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, <i>and</i> ☐ 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: ☒ <i>Explanation for including only RCTs</i> ☐ OR <i>Explanation for including only NRSI</i> ☐ OR <i>Explanation for including both RCTs and NRSI</i>		
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 <i>and</i> achieved good agreement (at least 80 percent), with the remainder selected by one reviewer.		

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	☒ Yes ☐ No	
☐ OR two reviewers extracted data from a sample of eligible studies <u>and</u> achieved good agreement (at least 80 percent), with the remainder extracted by one reviewer.		
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, <i>and</i> ☐ 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, <i>and</i> ☒ 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, <i>and</i> ☐ from selection bias	For Yes, must also have assessed RoB:	☐ methods used to ascertain exposures and outcomes, <i>and</i> ☐ 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		

11. If meta-analysis was performed did the review authors use appropriate methods for statistical combination of results?			
RCTs For Yes: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☒ 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 </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☒ Yes ☐ No ☐ No meta-analysis conducted </td> </tr> </table>		☒ 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
☒ 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: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☐ 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 </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☐ Yes ☐ No ☐ No meta-analysis conducted </td> </tr> </table>		☐ 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
☐ 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: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☐ 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. </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☒ Yes ☐ No ☐ No meta-analysis conducted </td> </tr> </table>		☐ 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
☐ 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: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☐ 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 </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☒ Yes ☐ No </td> </tr> </table>		☐ 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
☐ 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: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☐ 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 </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☐ Yes ☒ No </td> </tr> </table>		☐ 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
☐ 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: <table style="width: 100%; border: none;"> <tr> <td style="width: 70%; vertical-align: top;"> ☒ performed graphical or statistical tests for publication bias and discussed the likelihood and magnitude of impact of publication bias </td> <td style="width: 30%; vertical-align: top; border-left: 1px solid black; padding-left: 10px;"> ☒ Yes ☐ No ☐ No meta-analysis conducted </td> </tr> </table>		☒ 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
☒ 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		

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	☒ Yes
☐ The authors described their funding sources and how they managed potential conflicts of interest	☐ No