Age and Ageing 2019; **48:** 185–195
doi: 10.1093/ageing/afy164
Published electronically 24 October 2018

SYSTEMATIC REVIEWS

Interventions to improve adherence to exercise therapy for falls prevention in community-dwelling older adults: systematic review and meta-analysis

Katie J. Hughes, Nancy Salmon, Rose Galvin, Blathin Casey, Amanda M. Clifford

School of Allied Health, Faculty of Education and Health Sciences, Health Research Institute, University of Limerick, University of Limerick, Limerick, Ireland

Corresponding author Ms Katie Hughes, School of Allied Health, Faculty of Education and Health Sciences, Health Research Institute, University of Limerick, Limerick, Ireland, Email: Katie.Hughes@ul.ie

Abstract

Background: exercise therapy is highly recommended for falls prevention in older adults; however, poor exercise adherence may limit treatment effectiveness.
Objective: to assess the effectiveness of interventions to improve exercise adherence for community-dwelling adults (aged over 65 years), at risk of falling.
Methods: eight databases were searched to identify randomised/quasi-randomised trials. The Capability, Opportunity, Motivation model of behaviour (COM-B) was used to categorise the identified adherence interventions. Studies with similar interventions that provided adherence outcome data per group were analysed to establish pooled intervention effect. Protocol registration with Propsero: (CRD42016033677).
Results: of the 20 trials included (n = 4419), five provided data per group for adherence outcome. Meta-analysis of four studies (n = 482), containing interventions exploring the way exercise is delivered, demonstrated significantly better adherence in the intervention group (n = 166 experimental, n = 161 control Fixed effects model (FEM), SMD = 0.48 95% CI [0.26–0.70] $P < 0.0001$ $I^2 = 0\%$, very low GRADE evidence). Within this limited evidence base, interventions using telecommunication and the integration of exercise into activities of daily living appear most promising when delivering exercise at home. Meta-analysis to explore the effect that these interventions to improve adherence had on balance (n = 166 experimental, n = 161 control Random-effects model (REM), SMD = 0.82, 95% CI [−1.20–2.84] $P = 0.43$ $I^2 = 52\%$) and gait (n = 59 experimental, n = 56 control REM, SMD = 0.29, 95% CI [−1.62–2.20] $P = 0.77$ $I^2 = 48\%$), found no statistically significant effect.
Conclusions: adherence to exercise can be positively influenced; however, insufficient data exists to support any single intervention that also achieves effective outcomes for balance and gait.

Keywords

falls prevention, adherence, exercise therapy, older adults, systematic review

Key points

- It is possible to improve exercise adherence to falls prevention programs for community-dwelling older adults.
- This review synthesised and categorised interventions to improve exercise adherence for falls prevention using the COM-B model.
- The use of an adherence taxonomy and framework may help to define intervention functions and assist evidence synthesis.
- Multifactorial approaches may be necessary to achieve optimal adherence.
- The use of telecommunication and integration into activities of daily living appear to be promising interventions.

Introduction

Falls are the leading cause of injury to older adults, which can result in loss of independence, activity limitation and premature death [1]. Current clinical guidelines unanimously recommend exercise therapy (ET) to address strength, balance and gait deficits for all adults aged over 65 at risk of falling [2–4]. Specifically, ET is the most widely researched intervention for community-dwelling older adults with robust evidence demonstrating its effectiveness in reducing the incidence of falling [4–6].

Provided the correct exercise type and sufficient intensity are prescribed, gains in physiological health are largely determined by exercise dose [7]. Guidelines [2–4] suggest that exercise for falls prevention be completed for longer than 12 weeks, 1–3 times per week [3]. However; 3 h per week [6] accumulating a total dose of 50 h at a minimum [4] is recommended to achieve greatest effect. Poor exercise adherence is recognised as an important determinant that could limit the achievement of the desired exercise dose, subsequently impacting treatment effectiveness [6, 8, 9]. Adherence is defined as the extent to which a person's behaviour corresponds with agreed recommendations from a healthcare provider [8]. Over half (59%) of older adults engaging in group-based, and most (79%) completing home exercise programs (HEPs), struggle to fully accomplish their prescribed ET for falls prevention [10]. A higher proportion (80%), adhere during the early stages of their exercise program regardless of the method of delivery (individual or group); however, the average rate of adherence decreases as time elapses [9]. This limited achievement of ET dose is likely to affect the achievement of the therapeutic goal [11]. Therefore, understanding and addressing the reasons for non-adherence is important for treatment success.

Non-adherence to exercise in the older adult population appears to be influenced by individual factors (socioeconomic status, health, motivation, physical function and psychology) and program factors (method of delivery, and exercise location) [12]. Thus, even if a program is delivered with acceptable program factors, effectiveness may be limited to a self-motivated, capable, subgroup of individuals [9] who fully adhere.

While interventions to improve adherence have been hypothesised, evidence to establish their effectiveness in this population is warranted [5, 9, 13, 14]. The purpose of this systematic review is to critically appraise and synthesise the evidence base from randomised controlled trials (RCTs) to inform methods by which adherence to exercise-based interventions for falls prevention in community-dwelling older adults can be enhanced. A second aim is to explore if these trials with interventions to improve adherence achieve additional effectiveness for clinical outcomes. Such findings have implications for future research and those aiming to deliver effective services that maximise health outcomes.

Methods

This review is reported in accordance with PRISMA guidelines [15]. The protocol was registered with Propsero in March 2016 (CRD42016033677).

Eligibility criteria

Full-text, peer reviewed, randomised or quasi-randomised trials evaluating interventions to improve exercise adherence were included in this review. Studies that did not intervene to enhance adherence or measure and report exercise adherence were excluded. The target population was community-dwelling older adults (aged over 65 years) engaging in exercise for falls prevention. Falls were defined as 'an event whereby an individual unintentionally comes to rest on the ground or other lower level' [8] for reasons other than 'as a consequence of the following: loss of consciousness, sudden onset of paralysis, as in a stroke, and epileptic seizure' [16]. Studies targeting participants with neurological conditions (Parkinson's disease, multiple sclerosis, stroke) were therefore excluded. Studies were also excluded where participants were recruited due to a specific pathology (e.g. osteoporosis, osteoarthritis, visual impairment). In multi-arm trials, the targeted intervention and an equivalent control were required. See Appendix 1 for inclusion/exclusion criteria.

Search strategy

Medline, Embase, Cinahl, AMED, PsychINFO, Cochrane and Web of Science Core Collection databases were searched from inception to April 2018. Where appropriate, MeSH headings were used and search terms exploded, see Appendices 1–2. Forward citation searching of included studies was completed using Google scholar to identify articles added in the last year.

Study selection and data extraction

Study screening and data extraction were completed by the primary author. A second reviewer checked 25% of the studies selected at each stage of screening and 100% of data extracted for meta-analysis. If disagreement persisted a third author was consulted. Data pertaining to study characteristics (Appendix 2), methods employed to improve adherence (Table 1 and Appendix 5) and details of adherence and clinical outcomes (Tables 1, 2 and Appendix 4) were extracted to inform the primary study aim. Methods of adherence measurement were categorised according to completion (retention), attendance, duration and intensity [17] (Table 1). The authors utilised the COM-B model [18] to assist with synthesising and defining the content of the interventions identified (Table 1 and Appendix 5). This model recognises behaviour as being part of an interacting system involving capability, opportunity and motivation components. To influence a behaviour, interventions change one or more components to reconfigure the system and minimise the risk of reverting [18].

Methodological quality

Data was extracted and assessed independently by two reviewers using the CCRBT [19], see Appendix 3. Where

Table 1. Details of adherence measurement and adherence outcome data

Study	Method to improve adherence	COM-B domain			Measure(s) of Exercise Adherence (completion, attendance, duration, intensity)	Method of data gathering	Exercise dose Prescribed	Adherence Outcome
		CAP	OPP	MOT				
Buchner *et al.* [29]	Discharge planning intervention. Only delivered after the class therefore A3 is only relevant adherence outcome			✓	**A1) ATT**: at exercise sessions for 12 weeks **A2) INT**: achievement of target HR **A3) DUR**: Continued exercise at 6 months	**A1)** class record **A2)** in-class monitor **A3)** Self-report	**A1)** TD: 36 h **A2)** 75% of HRR **A3)** TD:72 h CTD:108 h	**A1)** 99-100% attendance* **A2)** 75% target HR achieved on average, range 69%-80% * **A3)** 78% reported exercise at least x2/week.
Boongird *et al.* [40]	Simplified combined HEP and falls prevention education embedded in primary care with telephone, home visit and additional support.	✓	✓	✓	**A1) DUR**: following the exercise program for at least 120 m per week	**A1)** weekly calendar	**A1)** TD: 104 h	**A1)** @ 3 months 29.6% reached desired 120 min/ week. @ 6 months 32.4% reached desired duration.
Campbell *et al.* [24]	Telephone contact from the physiotherapist		✓	✓	**A1) DUR**: Self-reported completion of exercise—still exercising at least x3/week	**A1)** monthly diary returned by post	**A1)** TD: unclear	**A1)** At the end of 2 years 31 (44%) of the 71 from the exercise group were still exercising at least 3x/week.
Dekker-van Weering *et al.* [37]	Home-based technology-supported self-management exercise program	✓	✓	.✓	**A1) COMP:** Number of sessions/week. **A2) DUR**: number of minutes during a training session	**A1)** captured by program	**A1)** 3 times per week **A2)** 30 min TD: 18h	**A1)** 68%. 2.3 (±1.4)° sessions in the first 6 weeks and 1.9 (±1.5) in the last 6 weeks. **A2)** 24 min (± 8.0)°
Duque *et al.* [36]	Exergaming (virtual reality system) and the use of progression through the levels with goals			✓	**A1) ATT**: at training sessions **A2) ATT**: at an exercise program gathered 9 months post-intervention	**A1)** class record **A2)** self-report	Twice per week for 6 weeks. 20 minute sessions. TD: 4 h	**A1)** 97% **A2)** 2% attending an exercise programme (either BRU or control)
El-Khoury *et al.* [25]	Integration of exercise into daily activity	✓	✓	✓	**A1) ATT** at each group session. **A2) COMP**: Self-reported completion of HEP	**A1)** class record **A2)** verbally to instructor at each session.	**A1)** TD = 94.9 sessions **A2)** HEP: TD = 96 session CTD: 192 sessions	**A1)** 53 (16-71), 55.8%◊ **A2)** Home sessions reported (*n* = 256): median 55.5, IQR 23-79.9* 57.8%◊
Gschwind *et al.* [30]	Exergaming (iStopfalls)		✓	✓	**A1) COMP:** no. of times program used, **A2) DUR**: number of hours exercising (with/without instruction) **A3) INT** measured via game level	**A1-A3)** captured by program	**A1)** TD: 96 sessions **A2)** TD: 48 h **A3)** UTD	**A1)** 43.75%◊ Used 42 (57) times. **A2)** 38.9%◊. 18.7 hrs total: 11.7 (22) with & 7(12.8) without instruction. **A3)** Game level 2.1 (3.9).

Continued

Table 1. Continued

Study	Method to improve adherence	COM-B domain CAP	OPP	MOT	Measure(s) of Exercise Adherence (completion, attendance, duration, intensity)	Method of data gathering	Exercise dose Prescribed	Adherence Outcome
Gschwind *et al.* [31]	Exergaming (Kinect & step-mat training)		✓	✓	**A1) DUR**: median time played over 16 weeks. **A2) DUR**: median time played per week **A3) INT** measured via game level	**A1-A3)** captured by program	**A1)** TD: 16 h **A2)** 3×20 min TD: 60 min	**A1)** Kin: 4.5(8.4) hrs 28.1%◊ and SMT: 12.7(25) h 79.4%◊ over 16 weeks. **A2)** Kin: 17(32) mins, 28.3%◊ and SMT: 48(94) min. 80%◊
Hars *et al.* [28]	Music-based multitask training with long-term group classes provided.		✓	✓	**A1) ATT** at group exercise sessions.	**A1)** class record	**A1)** TD: 45 h/year, 180 h over 4 years.	**A1)** 44.2% maintained regular attendance at classes over the 4-year follow-up.
Li *et al.* [41]	Strengthening perceptions of control to increase self-efficacy via Tai Chi			✓	**A1) ATT** at exercise sessions	**A1)** class record	**A1)** 2× 1 h sessions per week for 6 months. TD: 48 hours	**A1)** median compliance of 41/ 48 sessions, range of 29-47. 85.4%◊
Liu & Tsui [42]	Use of CBI but aim is to reduce fear of falling, not targeting adherence.	✓		✓	**A1) ATT** at weekly group sessions, **A2) DUR**: average hours spent on Tai Chi exercise per week during the 8-week intervention.	**A1)** class record **A2)** unclear	**A1)** 1 h classes for 8 weeks. TD: UTD **A2)** TD: 56 sessions, UTD time.	**A1)** 15 participants in Tai Chi & CBI group attended fewer than 50%, attendance in the TC alone group was all above 50%. **A2)** both groups spent 2.1 (2.2) hours/week.
Lord *et al.* [35]	Level of individualised support: supervision during exercise. Exercise diaries in EIG.	✓	✓	✓	**A1) ATT** a group classes. **A2) DUR**: number of times HEP sessions was performed weekly for those in EIG group who could not complete group programme	**A1)** class record **A2)** self-report	**A1)** TD: Average 78 classes **A2)** Not specified	**A1)** median number of classes attended: 21 (range 0–82). **A2)** 90%performed the partially supervised HEP twice weekly.
Niemela *et al.*, [26]	Novel exercise (rocking chair), phone call support and exercise diaries.	✓	✓	✓	**A1) DUR**: Exercise diary. Recorded daily for 6-week intervention period. **A2) DUR**: Mail questionnaire after 3 months to establish if the program was a regular exercise habit.		**A1)** 5 days per week 15 min sessions x 2 daily (150 min/2.5 h weekly) for 6 weeks. TD: 15 h **A2)** UTD	**A1)** overall adherence: 96%. 86% comp program at least x10/ week **A2)** after 3 months the RC ex became a regular HEP for 88.5% of the group.
Patil *et al.* [27]	Long-term supervised exercise and provision of pedometers may have encouraged increased PA.		✓	✓	**A1) ATT** at exercise sessions, **A2) INT**: measured as METs taken every 8 weeks **A3) DUR:** Time spent completing HEP	**A1)** class record (measured as % of all sessions offered). **A2)** HR monitors **A3)** diary	**A1)** TD: 156 h **A2)** Target METs not specified. **A3)** TD: 104 h CTD: 260 h	**A1)** 73% (range 0–97%) **A2)** mean exercise intensity 1.6–5.6 METs, individual maximum values were >7 METs. **A3)** 66% (range 0–100%)

Continued

Table 1. Continued

Study	Method to improve adherence	COM-B domain			Measure(s) of Exercise Adherence (completion, attendance, duration, intensity)	Method of data gathering	Exercise dose Prescribed	Adherence Outcome
		CAP	OPP	MOT				
Weerdesteyn *et al.* [33]	Choice of low intensity and short duration of programme.	✓			**A1) ATT** rate at each training session	**A1)** class record	**A1)** 1.5 h sessions x2 weekly for 5 weeks. TD: 15 h	**A1)** mean attendance 87%°. 51% attended a maximum number of ten sessions
Zijlstra *et al.* [39]	CBT approach-cognitive restructuring.		✓	✓	**A1) ATT** at each session **A2) DUR**: of HEP, collected at 2, 8 and 14-month follow-up **A3) COMP:** HEP completeness	**A1)** class record **A2)** Self-reported **A3)** Facilitator impression	**A1)** TD: CBI: 18 h Ex: 1.5 h	**A1)** 57.9% attended at least five sessions. Average 6.8 sessions of nine attended =75.5%. **A2)** 74.9% usually or always did HEP **A3)** 30%
Clemson *et al.* [38]	Embedding exercise in daily activity.	✓	✓	✓	**A1) DUR**: % exercise completed. **A2) COMP**: Exercise maintenance – still doing exercises. **A3) DUR**: Exercise frequency and type for LiFE group.	**A1-A3)** self-report log	LiFe: as opportunity arises TD: UTD Structured: TD: 72 h control: TD: UTD	**A1)** @ 6 months; LiFE: 47 (33)%, struct: 35(29)%, con: 47(34)%. Adherence to struct ex sig lower (F ratio =4.69, P = 0.01). **A2)** @ 12 months – LiFe: 64%, struct: 53%, sham: 53%. **A3)** 3.89 (2.13) days/week were exercised* (n = 61)
Hagedorn & Holm [32]	Computer feedback training-Exergaming.			✓	**A1) ATT** at each of the classes NOTE: four participants excluded as they attended < 12/24 sessions	**A1)** class record	**A1)** TD: 24 sessions, 36 h.	**A1)** TB:67.9% CB:72.9%
Lacroix *et al.* [34]	Level of SUP during exercise. Hypothesis is that UNSUP may adhere better		✓		**A1) ATT**: SUP group **A2) COMP:** of UNSUP HEP	**A1)** class record **A2)** via self-report log	**A1)** TD: 27 h (Sup: 18 h sup & 9 h HEP). Unsup: 27 h HEP	**A1)** 92% **A2)** 94.7% (in SUP group) and 97.4% (in UNSUP group (self-report)).
Wu *et al.* [43]	Method of exercise delivery & phone call every 2 weeks as reminder to complete log.		✓	✓	**A1) ATT/COMP** at class sessions/HEP **A2) DUR**: time exercised (h) in and out of class	**A1 & A2)** gathered via log sheet (returned at the end of the study).	**A1)** 45 sessions **A2)** TD: 45 h	**A1)** Tele-Ex:69%°, and Comm-Ex:71%° had sig higher (P < 0.01) ATT, than Home-Ex: 38%°. **A2)** Tele-Ex 30(12) h and Comm-Ex 31(12) hrs, had sig higher ex times versus Home-Ex 17(21) (P < 0.001).

*: indicates that data pertains to those who did not dropout, †: indicates that data pertains to all participants, including dropouts. °: indicates mean(SD), ◊:indicates median (IQR). CAP: capability, OPP: opportunity, MOT: motivation, ATT: attendance, COMP: Completion, DUR: duration, INT: intensity, TD: total dose, CTD: combined total dose, UTD: Unable to determine, SUP: supervised, UNSUP: unsupervised, Struct: Structured; ICT: Information communication technology, BST: balance and strength training.

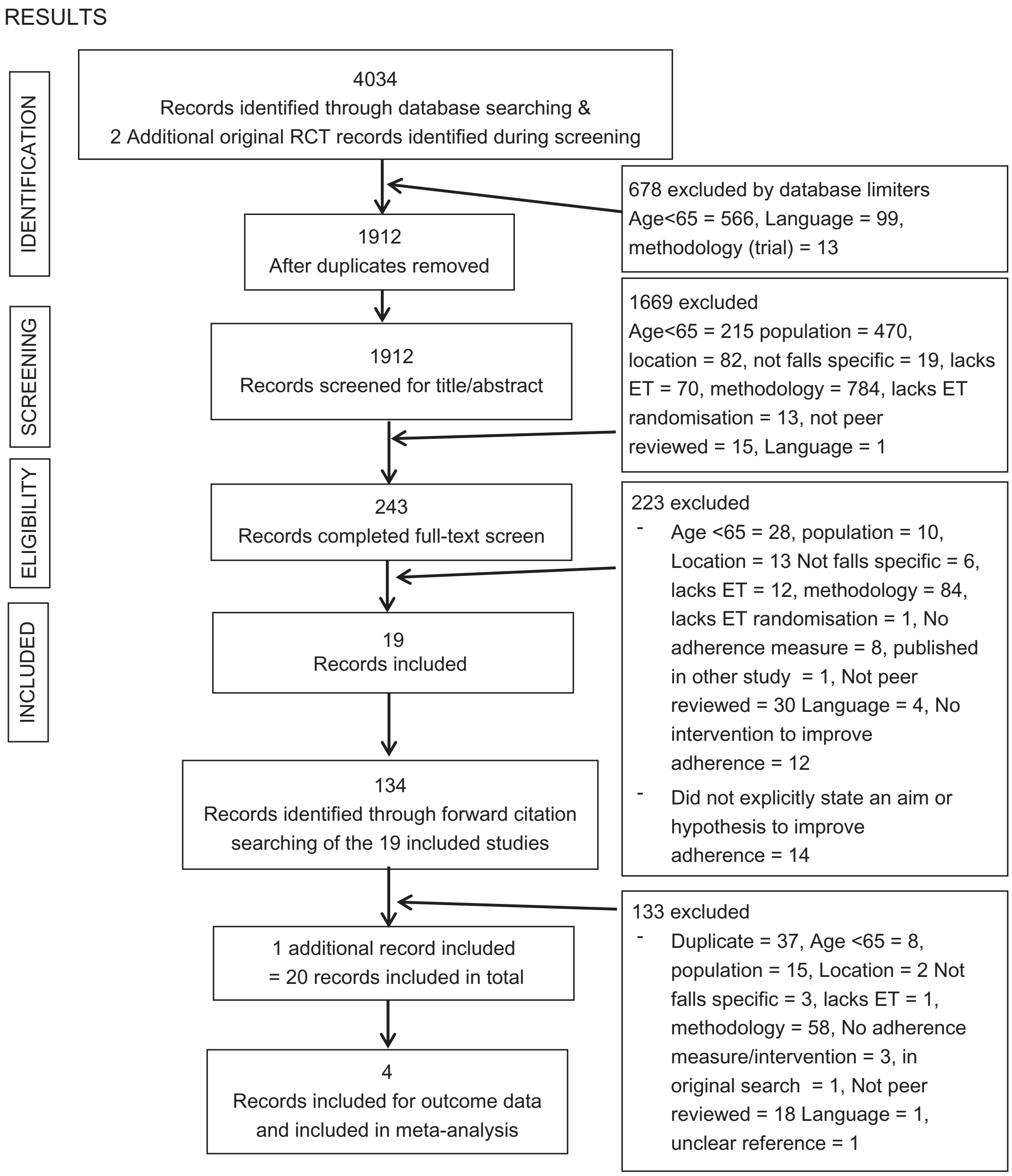

Figure 1 Prisma flow diagram.

agreement was not met, a third reviewer was consulted. Studies were deemed to be at highest risk of bias (RoB) if they scored high or unclear for sequence generation or allocation concealment domains based on growing empirical evidence that these factors are particularly important sources of bias [**20**].

Synthesis of results

Synthesis involved two stages. Firstly, descriptive data and study outcome details were narratively synthesised and tabulated. Secondly, studies with similar interventions to improve adherence, that provided sufficient data for adherence outcome per group, were pooled and analysed using Cochrane Review Manager software (RevMan, V.5.3). Where an included study had missing data to allow dose calculation, missing adherence outcome per group or when the mean/median or standard deviation/IQR was not reported, authors were contacted (Figure 1).

Although included studies were methodologically homogenous, heterogeneity was anticipated in ET type, comparison groups and outcome measurement. To address this, the I^2 statistic was assessed. We considered an I^2 of greater than 50% substantial [21], hence, if I^2 was ≥50%, we reported a more conservative random-effects model (REM). If I^2 was ≤50% we used a fixed-effect model (FEM). As different instruments were employed to assess the same outcome (adherence, balance and gait) the standard mean difference with 95% CI was used as the primary measure to assess treatment effect. Effect sizes (ES) below

Table 2. Outcome of studies with per arm data for interventions to improve adherence.

Study	Adherence Outcome	Balance outcome	Gait outcome	Falls outcome
Clemson *et al.* [38]	Life ‡ Struct § CON completion (%): first 6 months: 47(33) 35(29) 47(34) completion (%): end of 6 months 81(76) 63(60) 74(71) completion (%): end of 12 months 68(64) 56(53) 56(53)	Life ‡ Struct § CON 26 (20) 31.9 (23.7) 40.7 (24) Tandem walk time Outcome at 6 months	N/M	Significant reduction in the rate of falls (31%) in the LiFE group
Lacroix *et al.* [34]	Sup § Unsup ‡ CON Attendance (%) at sup sessions 91.7(7.9) N/A Completion (%) for unsupervised. N/A 97.4(7.0)	Sup § Unsup ‡ CON 0.67(1.0) 1.0(0.33) 1.0(0.67) Push Release Test Post int@ 12 weeks	Sup § Unsup ‡ CON 8.78(1.08) 9.43(1.02) 9.66(1.19) TUG Post int @ 12 weeks	N/M
Hagedorn & Holm [32]	CB ‡ TB § Class attendance 17.5 16.3	CB ‡ TB § 42.5(6.2) 41.8(7.2) BBS. Post int @ 12 weeks	CB ‡ TB § 14.6(5.8) 18.1(6.4) TUG. Post int @ 12 weeks	N/M
Liu & Tsui [42]	TC&CBI ‡ TC § Tai Chi: hours per week 2.1 (2.2) 2.1 (2.2) Attendance fewer than 50% All > 50%	TC&CBI ‡ TC § 15.46(0.91) 15.82(0.44) Tinnetti Balance Post int @ 8 weeks	TC&CBI ‡ TC § 11.61(0.68) 11.64(0.80) Tinnetti Gait Post int @ 8 weeks	N/M
Wu *et al.* [43]	Tele-ex ‡ Com-Ex H-ex § Attendance (%) 69(27) 71(27) 38(46) In-Class practice time 30(12) 31(12) 17(21)	Tele-ex ‡ Com-Ex H-ex § 1.6(3.9) 3.9(7.5) 1.3(4.2) Single leg stance Post int change @ 15 weeks	Tele-ex ‡ Com-Ex H-ex § −0.8(6.7) −0.2(1.2) 0.0(0.8) TUG Post int change @ 15 weeks	Tele-ex and Com-Ex: sig reduction in mean no. of falls & injurious falls

‡: indicates intervention group in analyses, §: indicates control group in the analysis, N/M: No measure, int: intervention, sig: significant, CON: control, SUP: supervised, UNSUP: unsupervised, CB: computerised balance, TB: traditional balance, BBS: Berg balance scale, TUG: timed up and go.

0.2 were classified as small, 0.2–0.5 as medium and greater than 0.5 as large [**22**]. The GRADE criteria was used to rank the quality of the evidence [**23**].

Results

Twenty papers (n = 4419 participants) were included in this review, See Appendix 2. Four trials had females exclusively [24–27], yet no trials were male only. Length of follow-up ranged from 7 weeks [26] to 48 months [28]. The individual delivering the exercise was unclear [26, 29–33] in six cases. Exercise instructors delivered the intervention in five studies [25, 27, 28, 34, 35], physiotherapists/occupational therapists in four studies [24, 36–38], nurses in two studies [39, 40] and Tai Chi instructors in three studies [41–43].

Seventeen studies (85%) were scored as having a high RoB [24–30, 32–34, 36, 37, 39–43] and three were scored as unclear [31, 35, 38]. No study had a low RoB. Lack of participant blinding and no allocation concealment were the most frequent sources of high and unclear scoring. See Appendix 3.

Attendance and duration were the most frequent measures of adherence (n = 13), followed by exercise completion (n = 6), see Table 1. Adherence to prescribed exercise intensity was measured in five studies [27, 29–31, 34]. Two studies used a therapist report of adherence by gathering in-class exercise time [43] or the facilitator's impression of HEP completion [39]. One study measured accuracy of exercise completion [40].

Exercise dose estimation was not feasible in six trials [24, 25, 35, 38, 39, 42]. Three lacked detail for exercise time [24, 25, 42], while two provided exercise class time but not HEP time [35, 39]. One study explored exercise embedded in daily activity using a unique ranking system, rather than explicit exercise time [38]. Of the 14 studies for which total dose was calculated, only four delivered an exercise dose of ≥50 h [27–29, 40].

Six studies delivered ET using a mixture of group-based/in-clinic treatment and HEPs [25, 27, 29, 35, 39, 42]. Supervised exercise consisted mainly of structured classes or supervised home visits [24, 40]. Doses delivered via class exercise only [28, 32, 33, 36, 41] ranged from 4 [36] to 180 h [28]. Unsupervised hours consisted mainly of HEPs completed autonomously. Doses delivered via HEP only [26, 30, 31, 37, 38, 40] ranged from 15 [26] to 104 h [30, 40]. Two studies specifically tested the delivery of exercise in a supervised, unsupervised [34] or remotely supervised manner [43], see Table 2.

Narrative synthesis

Fifteen studies were narratively synthesised due to the absence of a control group engaging in the exercise programme but not receiving the adherence intervention. For

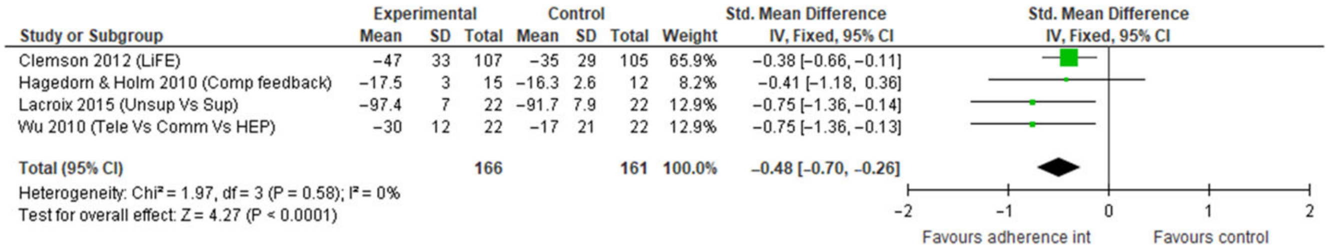

Figure 2 Meta-analysis result for effectiveness of intervention to improve adherence on adherence outcome.
LiFE: Intervention where home-exercises were integrated into activities of daily living compared to a traditional structured HEP control group. [outcome: % exercise completion; RoB: Unclear]
Comp feedback: Intervention where the delivery of balance exercises in-clinic was completed using a visual computerised feedback training platform to train balance via exergames compared to conventional balance training. [outcome: class attendance. RoB: High]
Unsup Vs Sup: Intervention where identical exercise programs were delivered in a supervised manner (x2 supervised by an instructor at a local gym and x1 unsupervised at home) and an unsupervised manner (x3 unsupervised at home). [outcome: attendance at SUP sessions and % completion of UNSUP sessions. RoB: High]
Tele Vs Comm Vs HEP: A three-arm trial comparing a Tai Chi exercise program delivered through a live, interactive, telecommunication-based exercise (Tele) with that of a similar program through a community center-based exercise (Comm) and a home video-based exercise (HEP) [outcome: in-class practice time. RoB: High].

attendance outcome the lowest rate, 27%, was identified in a 48-week combined class and HEP program [35]. The highest attendance, 97%, was to a 6-week balance training class using a virtual reality system [36]. For duration outcome the lowest adherence rate, 28% was identified in a 16-week HEP only trial using an exergaming device [31]. The highest rate, 96%, was to a 6-week rocking chair based HEP [26]. Unfortunately, due to the inability to establish outcome effect versus a suitable control, recommendations regarding the effectiveness of these interventions could not be established. However, the content of these interventions and those included in the meta-analysis could be synthesised using the COM-B model (Table 1 and Appendix 5).

Motivation for exercise was the COM-B domain encountered most frequently (n = 16). Interventions involved using exergaming [30–32, 36], providing phone call support or remote instruction via telecommunication [24, 26, 40, 43], planning [29], goal setting [39], targeting self-efficacy via Tai Chi practice and CBT [41, 42], educating to target beliefs about exercise [40], using novel exercise methods (e.g. music-based multitasking [28], rocking chair exercise [26]) and integrating exercise into daily activity to foster habitual engagement [25, 38]. Monitoring exercise behaviour via diaries [35] or automatically using technology solutions [27, 37] were also identified.

Thirteen studies had interventions linked to the COM-B opportunity component. Many strategies involved making exercise more accessible via delivery of unsupervised HEP [25, 26, 30, 31, 37, 38, 40]. While others delivered supervised exercise in person [34, 35] or using technology solutions [43]. The provision of home visits [37, 40], therapist support by phone [24] and the integration of exercise into ADL's [25, 38] were used to increase opportunity for HEP adherence. Long-term class-based exercise [27, 28], free transportation, reduced session frequency and delivery in local settings [39] were encountered for class-based programs.

The capability domain was encountered in 11 studies. Interventions involved offering additional appointments [37], prolonged supervision [27, 28], individualising ET [35, 40], completing exercise via ADLs [25, 38], offering a seated program [26] or a short, low intensity program [33] and focusing on psychological capability [42].

Meta-analysis

Five studies [32, 34, 38, 42, 43] provided sufficient data per group to inform on adherence and clinical outcome effectiveness, See Table 2. Of these, four delivered interventions targeting exercise program factors to improve adherence and compared their intervention to traditional exercise delivery methods [32, 34, 38, 43]. Meta-analysis of this data shows significantly better adherence in the intervention group versus control, n = 166 experimental, n = 161 control FEM, SMD = 0.48 95% CI [0.26–0.70] $P < 0.0001$ $I^2 = 0\%$, see Figure 2. Use of the GRADE criteria to assess the quality of this evidence found very low GRADE evidence due to inconsistency, imprecision, indirectness and a high risk of bias, see Appendix 6. One study not included in the meta-analysis found that the addition of CBT to Tai Chi exercise did not achieve greater attendance or HEP completion.

This review found support for the use of telecommunication and the integration of exercise into ADLs to improve HEP adherence compared to traditional structured HEPs. Additionally, an unsupervised HEP, measured by self-reported completion, was found to yield significantly better adherence than for class-based supervised exercise, measured by attendance. The use of computerised feedback training for exercise delivery in-clinic versus traditional balance exercise yielded better class attendance, but this finding was not statistically significant.

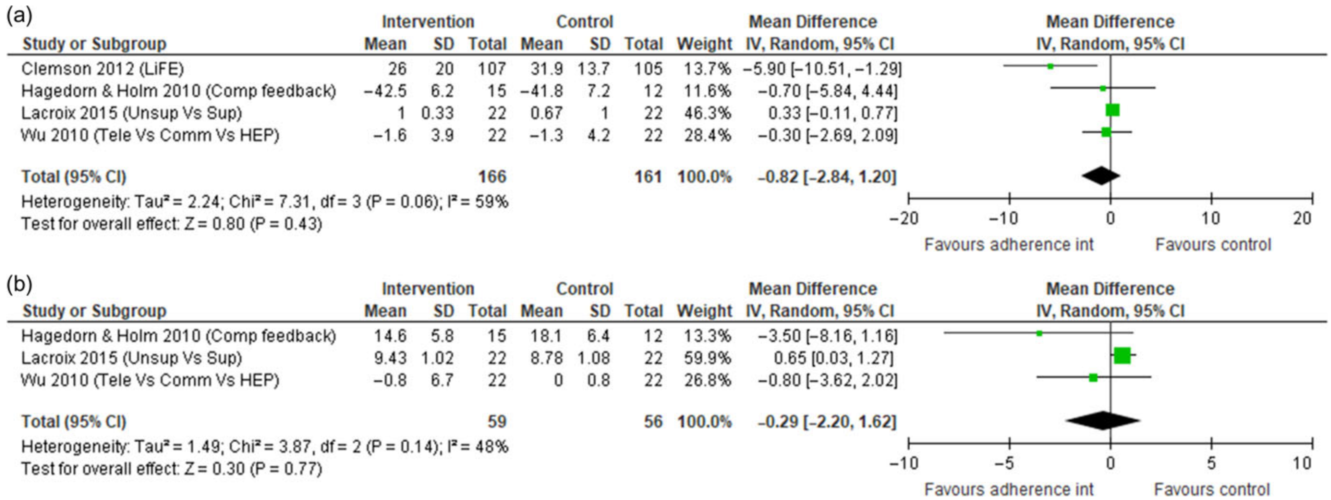

Figure 3 (a) Meta-analysis result for effectiveness of intervention on balance outcome. (b) Meta-analysis result for effectiveness of intervention on gait outcome.

Figure 3 (a) and (b), details the results of meta-analysis to explore the resulting effects that the interventions to improve adherence had on clinical outcomes. As many trials did not report falls incidence; measures of balance and gait were used to inform clinical outcome. REM meta-analysis found a pooled SMD of 0.82 for balance outcome (Figure 3a), [n = 166 experimental, n = 161 control REM, 95% CI [−1.20–2.84] P = 0.43 I^2=52%] and 0.29 for gait outcome (Figure 3b) [n = 59 experimental, n = 56 control REM, 95% CI [−1.62–2.20] P = 0.77 I^2=48%]. These results indicate that there was no statistically significant improvement in balance and gait outcomes in the intervention arms hypothesised to have greater adherence, versus the control.

Discussion

This review found that interventions targeting exercise program factors to improve adherence achieved a moderate, positive effect on exercise adherence to falls prevention programs in older adults. This finding has potential clinical significance as the level of patient adherence to the exercise regimen directly influences the exercise dose achieved. It has been established that increased exercise dose yields greater treatment outcome for falls prevention [4]; therefore, it is logical to hypothesise that the substantial increase in adherence observed in this meta-analysis would lead to improved treatment outcome. Yet, this hypothesis cannot be supported by the current meta-analysis or a previous review [9] for clinical outcomes of balance and gait. This may be due to a small and somewhat conflicting body of evidence with high presence of bias, as demonstrated by the very low GRADE assessment finding in this review, inaccurate or indirect measurement of exercise adherence or failure to reach a threshold for detectable change on clinical outcomes. Therefore, these results for interventions to improve adherence should be interpreted with caution and considered in the context of a lack of data to also support improved clinical outcomes.

The meta-analysis in this review contained four studies to inform the effect of interventions to improve adherence on adherence outcome. Three had interventions influencing the motivation domain of the COM-B model, two influenced opportunity for exercise adherence and one influenced capability. Synthesis of interventions using the COM-B model [18] in this review is the first attempt to categorise interventions to improve exercise adherence for falls prevention using this model. Interestingly, studies in both the meta-analysis and narrative synthesis combined many methods to improve exercise adherence, suggesting that multifactorial interventions may be required to improve exercise adherence behaviour. Multifactorial intervention to improve adherence in two studies that also demonstrated a significant reduction in clinical outcome, measured as falls incidence, [38, 43] supports this hypothesis, however; further data is required before conclusions can be drawn. Understanding the context as to why interventions may be successful and the specific means by which successful interventions change adherence behaviour are important gaps in the current evidence base. Our understanding of context could be addressed using novel methods of co-design or process evaluations of successful interventions. While specific knowledge advising the behaviour change functions of interventions can be facilitated by more detailed reporting and the use of a framework for accurate reporting. The Behaviour Change Wheel [18] provides a suitable framework detailing intervention functions and offers standardised ways to approach the design and evaluation of behaviour change interventions.

Considering narrative and meta-analysis findings in this review and the broader evidence base [10, **12**–14], program factors, such as location, ET time, type, frequency, intensity and the level of supervision/contact, appear important for adherence behaviour. While this knowledge is a useful starting point to inform a behaviour change strategy for exercise adherence in this population, the next step is to expand the evidence base, assessing what program factors give the best results for both adherence and clinical outcomes.

Findings from two studies in this review [34, 43] comparing supervised versus unsupervised exercise demonstrated conflicting results for adherence outcome. However, results for gait outcomes were superior for supervised exercise in both studies. This suggests that although participants reported better adherence when unsupervised, the quality, accuracy and intensity of exercise could be sub-optimal, therefore limiting clinical outcome. Variation in methods of adherence measurement, e.g. objective (class attendance) versus self-report measures (HEP completion), limit the interpretation of these results, and are subject to recall bias. Therefore, further exploration using valid objective measurement to establish which mode(s) of delivery are most effective for both adherence and clinical outcomes is warranted.

Despite the potential benefits of supervised ET, a transition to long-term autonomous exercise is likely in most programs implemented clinically. This is reflected by most studies in this review using a HEP component either in isolation (n = 5) or in conjunction with a class or home visits (n = 8) to deliver the ET dose. As both group/class and HEP interventions have demonstrated effectiveness [4], decisions regarding delivery mode are likely to be made considering the geography, resources, need for individualisation, and socialisation [**44**]. Interventions targeting HEP adherence in this review address some known barriers to exercise in this population. HEPs may overcome challenges when travelling to group classes at structured times and participants may prefer exercising autonomously as self-regulation is possible [**45**]. Linking exercise to ADLs may improve cues for exercise, as linking actions to situations permits external cueing, which may avoid the monitoring and planning required for structured exercise [46]. However, as social encouragement is an important patient preference [9, **45**] its absence from unsupervised HEPs requires further investigation. The use of group ET to allow peer observation as a strategy target social opportunity [18], is also lacking in individualised programs, unless communication technology strategies are used. As capability was only targeted by one intervention in the meta-analysis and 11 overall, the importance of considering the known physical and psychological barriers to adherence in this population is advised [9, **12**].

The use of technology to enhance adherence was identified in half of the studies in this meta-analysis and in a third of studies overall. While concerns that technology solutions may be viewed as a panacea [**47**], their use to motivate, via computerised feedback [32] or exergaming [30–32, 36], facilitate objective performance monitoring [27, 30–32, 36] and offer remote support, education and guidance were evident in this review. In particular, telecommunication appears as an effective platform to improve adherence at home [43], but supporting evidence is currently not sufficient to make recommendations.

The requirement for randomised trials and material written in English language only limited the breadth of data reported in this review. While no inconsistencies between authors were found, 100% data checking was not achieved. As measurement of falls incidence was scarce it was difficult to establish these findings within the evidence base for falls prevention. The quality of available evidence restricts the impact of these findings, therefore efforts to address methodological limitations are advised. As performance and selection bias were the most frequent high RoB sources, methods to blind participants and personnel to group allocation with adequate concealment should be ensured.

Conclusions

It is possible to improve exercise adherence to falls prevention programs for community-dwelling older adults. Multifactorial approaches may be necessary to achieve optimal adherence and should be guided by theory-based and/or evidence-based modifiable factors which are known to influence adherence. The use of a behaviour change taxonomy and adherence framework may help to define intervention functions, guide future research and assist in evidence synthesis. Valid and reliable adherence measurement combined with clear reporting of exercise parameters are required in future trials.

Supplementary data mentioned in the text are available to subscribers in *Age and Ageing* online.

Declaration of Sources of Funding: The lead author, Katie Hughes, is in receipt of a fee waiver scholarship from the University of Limerick to complete her PhD studies. This paper is a result of this doctoral work, otherwise no additional funding supported this research.

Declaration of Conflict of Interest: None.

List of abbreviations

ADLs: activities of daily living
BCT: Behaviour change technique
CBT: Cognitive behavioural therapy
CCRBT: Cochrane Collaboration Rick of Bias Tool
CERT: Consensus on Exercise Reporting Template
CI: Confidence interval
COM-B: Capability, opportunity, motivation model of behaviour
ET: Exercise therapy
FEM: Fixed effects model
HEPs: Home exercise programs
IQR: Interquartile range
OR: Odds ratio
REM: Random-effects model
RoB: Risk of bias

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses
h: hour(s)
SMD: Standard mean difference

References

PLEASE NOTE: This is a shortened reference list. The full list of references supporting this review is available as Appendix 7 in the supplementary material via the journal website.

2. NICE, Falls in older people: assessing risk and prevention. 2013, National Institute for Health and Care Excellence Manchester.

3. AGS/BGS. Guidelines for the prevention of falls in older persons. J Am Geriatr Soc 2011; 49: 664–72.

4. Sherrington C *et al.* Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. New South Wales Public Health Bull 2011; 22: 78–83.

5. Gillespie LD *et al.* Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev 2012; 9: 11.

6. Sherrington C *et al.* Exercise to prevent falls in older adults: an updated systematic review and meta-analysis. Br J Sports Med 2016;1–10.

9. Nyman SR, Victor CR. Older people's participation in and engagement with falls prevention interventions in community settings: an augment to the cochrane systematic review. Age Age 2012; 41: 16–23.

10. Simek EM, McPhate L, Haines TP. Adherence to and efficacy of home exercise programs to prevent falls: a systematic review and meta-analysis of the impact of exercise program characteristics. Prev Med 2012; 55: 262–75.

14. McPhate L, Simek EM, Haines TP. Program-related factors are associated with adherence to group exercise interventions for the prevention of falls: a systematic review. J Physiother 2013; 59: 81–92.

17. Hawley-Hague H *et al.* Review of how we should define (and measure) adherence in studies examining older adults9 participation in exercise classes. BMJ Open 2016; 6: e011560.

18. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci 2011; 6: 42.

24. Campbell AJ *et al.* Falls prevention over 2 years: a randomized controlled trial in women 80 years and older. Age Ageing 1999; 28: 513–8.

25. El-Khoury F *et al.* Effectiveness of two year balance training programme on prevention of fall induced injuries in at risk women aged 75–85 living in community: Ossébo randomised controlled trial. BMJ 2015; 351: h3830.

26. Niemelä K *et al.* Benefits of home-based rocking-chair exercise for physical performance in community-dwelling elderly women: a randomized controlled trial. Aging Clin Exp Res 2011; 23: 279. doi: 10.1007/BF03337754.

27. Patil R *et al.* Effects of a multimodal exercise program on physical function, falls, and injuries in older women: a 2-year community-based, randomized controlled trial. J Am Geriat Soc 2015; 63: 1306–13.

28. Hars M *et al.* Effect of music-based multitask training on cognition and mood in older adults. Age Age 2013; 43: 196–200.

29. Buchner D *et al.* A comparison of the effects of three types of endurance training on balance and other fall risk factors in older adults. Aging Clin Exp Res 1997; 9: 112–9.

30. Gschwind YJ *et al.* ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial. Eur Rev Aging Phys Act 2015; 12: 10.

31. Gschwind YJ *et al.* The effect of sensor-based exercise at home on functional performance associated with fall risk in older people—a comparison of two exergame interventions. Eur Rev Aging Phys Act 2015; 12: 1–9.

32. Hagedorn D, Holm E. Effects of traditional physical training and visual computer feedback training in frail elderly patients. A randomized intervention study. Eur J Phys Rehabil Med 2010; 46: 159–68.

33. Weerdesteyn V *et al.* A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly. Gerontology 2006; 52: 131–41.

34. Lacroix A *et al.* Effects of a supervised versus an unsupervised combined balance and strength training program on balance and muscle power in healthy older adults: a randomized controlled trial. Gerontology 2016; 62: 275–88.

35. Lord SR *et al.* The effect of an individualized fall prevention program on fall risk and falls in older people: a randomized, controlled trial. J Am Geriatr Soc 2005; 53: 1296–1304.

36. Duque G *et al.* Effects of balance training using a virtual-reality system in older fallers. Clin Interv Aging 2013; 8: 257.

37. Dekker-van Weering M *et al.* User experience, actual use, and effectiveness of an information communication technology-supported home exercise program for pre-frail older adults. Frontiers Med 2017; 4: 208.

38. Clemson L *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: e4547.

39. Zijlstra G *et al.* Effects of a Multicomponent Cognitive Behavioral Group. Intervention on fear of falling and activity avoidance in community-dwelling older adults: results of a randomized controlled trial. J Am Geriatr Soc 2009; 57: 2020–8.

40. Boongird C *et al.* Effects of a simple home-based exercise program on fall prevention in older adults: a 12-month primary care setting, randomized controlled trial. Geriatr Gerontol Int 2017; 17: 2157–63. DOI:10.1111/ggi.13052.

41. Li F *et al.* Tai Chi enhances self-efficacy and exercise behavior in older adults. J Aging Phys Act 2001; 9: 161–71.

42. Liu YWJ, 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. Arch Gerontol Geriatr 2014; 59: 317–25.

43. Wu G *et al.* Comparison of telecommunication, community, and home-based Tai Chi exercise programs on compliance and effectiveness in elders at risk for falls. Arch Phys Med Rehabil 2010; 91: 849–56.

Received 31 January 2018; editorial decision 17 August 2018