Effects of physical activity on functional health of older adults: a systematic review

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Title Page

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Abstract

Reviews on the relationships between functional health and physical activity of general older adults have been well documented in literature. However, specific age range of older adults, in particular, older adults of 75 years or above, is currently under-examined. A systematic review was conducted to investigate the effects of physical activity on functional health older adults aged 75 years or above. The reviewed articles cover a variety range of functional health outcomes, including balance, muscle conditioning, joint range of motion, quadriceps strength, reaction time, gait speed, health-related quality of life, back and knee pain, muscle mass, and walking ability. In general, interventions of the reviewed articles had favorable effects on function health of older adults. While physical activity has been identified as an important determinant of functional health, the ways to engage in and accumulate sufficient daily physical activity warrant investigation. It is also important to explore interventions which enhance daily, self-driven physical activity of elderly, as normally supervised physical activity bears higher costs.

Introduction

A recent projection showed that life expectancy will break the 90-year barrier by 2030 [1]. The increased longevity indicates the need for healthcare planning for the aging population and the accompanied growing disease burden. The body of evidence shows that frailty increases with age [2], and that functional health of an individual is associated with daily physical activity [3, 4, 5]. Reviews on the relationships between functional health and physical activity of general older adults have been well documented in literature [6]. However, specific age range of older adults, in particular, older adults of 75 years or above, is currently under-examined. As the life expectancy is going to break the 90-year barrier, it is of paramount importance to examined population group of older age range in an attempt to introduce tailor-made interventions that can prevent and delay frailty of older adults.

Methods

Search protocol

A keyword search in the subject and title categories of four electronic databases was performed: MEDLINE, CINAHL, EMBASE and SPORTDiscus.

Two sets of search terms were used to look into the physical trials of older adults with functional incapacity in activities of daily living [7, 8]. The first set of terms related to senior populations consisted of aged, aging, ageing, old, older, elder, elderly, senior, geriatric and gerontology.

The second set of terms pertained to the functional health: functional health, functional capacity, physical health, physical capacity, physical function, physical functioning, activities of daily living and instrumental activities of daily living. Physical trial search terms included intervention, training, activity, exercise, program, program and randomized controlled trial.

The searches were limited to English and full text. There was no limitation by publication year. Since this study does not involve meta-analyses, means and standard errors [9] of effect size were not computed.

Study identification

The title, keywords, and abstracts were screened to identify potentially relevant studies. When the abstract indicated relevance, the full text paper was retrieved and a final decision made about inclusion of the study. The inclusion criteria were: (a) empirical studies that included interventions (which include training, program, or exercise); (b) interventions aimed at the improvement of functional health in older adults; (c) participants 75 and older; and (d) English. The primary exclusion criterion was: participants living in hospital, nursing or care homes.

Results

Search results

The initial search yielded 29,898 articles. Based on the titles and abstracts, 33 studies were further reviewed, of which 14 fulfilled the study inclusion criteria [(10-23)]. The remaining articles were excluded for the following reasons: 8 did not apply physical intervention, 5 recruited participants living in hospitals, nursing or care facilities, 2 were not focused on functional health, 4 were not primary research. Of the 14 studies that met the inclusion criteria, only two did not apply randomized controlled trial. For each eligible study, information extracted and recorded included: (a) last name of the first authors and year of the study's publication; (b) description of participants; (c) duration of intervention; (d) focus of functional health; (e) general information of intervention and control group; (f) outcome measurement tools; and (g) results. In general, interventions of the reviewed articles had favorable effects on function health of older adults (Appendix A)

Functional health outcomes

The reviewed articles cover a variety range of functional health outcomes, including balance, muscle conditioning, joint range of motion, quadriceps strength, reaction time, gait speed, health-related quality of life, back and knee pain, muscle mass, and walking ability.

Intervention design

All except two of the reviewed articles had both intervention and control groups. Intervention groups included the use of elastic bands and balance exercises, resistance and agility training, coordination and reaction training, chair exercise, and gait training. Control groups included a health educational program, stretching classes, relaxation techniques teaching, posture education, social visits, flexibility exercises and memory tasks.

Measurements

Most reviewed articles adopted both subjective and objective assessments on functional health, including self-reported activities of daily living, health-related quality of life, and fear of falling and depressive symptoms. Objective assessments included mobility testing, posture stability test, 30-second chair stand test, balance test, gait speed, calf girth, knee extension strength, body composition measurement, and grip strength.

Discussion

As healthcare technology advances, long life expectancy is expected. Aging has become a vital and important issue attracting the world's attention due to the huge costs imposed on the healthcare sector. In this connection, interventions to prevent and delay functional decline of older adults are meaningful and not to be ignored. The body of evidence supports a variety of approaches to prevent and delay age-related functional decline. For example, resistance training that improves muscular strength and endurance; balance exercise that prevents the risk of falls; and aerobic training that enhances cardiorespiratory capacity. Interventions using physical activities and exercises to improve functional health of general older adults have been extensively documented. Interventions targeting specific age range of older adults, however, are rare. As life expectancy is going to break the 90-year barrier, it is important to divide older adults into smaller age-range, as different age groups may have different level of functional decline and thus respond differently to specific interventions. However, systematic reviews on the relationships between functional health and physical activity of older adults beyond 75 years old are rare. Therefore, this study will examine the relationships between functional health and physical activity of older adults under different age range.

Results of this study are consistent with the extent of literature, that physical activity, in general, can improve the functional health of older adults [24-35]. While physical activity has been identified as an important determinant of functional health, the ways to engage in and accumulate sufficient daily physical activity warrant investigation. For example, traditional resistance training may have low adherence and therefore the incorporation of exercise games and functional training becomes necessary [25]. It is also important to explore interventions which enhance daily, self-driven physical activity of elderly, as normally supervised physical activity bears higher costs. In addition, the assessments of functional health, including subjective and objective measures [36], call for more investigations on their reliability and validity, especially when these measurements are carried out for participants at the age of 75 and above who have different cognitive and physical abilities. Evidences have shown that objective measurements are vital to improve the objectivity [37-41]. Limitations of this study pertain to the absence of meta-analyses and in-depth statistical approaches [42,43] which may affect the findings of this study [44].

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Appendix A

Authors and year, Participants' description, Duration of intervention	Focus of Functional Health	Intervention & Control	Measurements	Results
● Gill et al., 2004 ● 188 persons (aged ≥75, mean=83) who were physically frail (determined by rapid gait and single chair stand tests) and living at home ● 6-month intervention	● Joint range of motion ● Balance, and muscle conditioning and strengthening ● Ability to perform instrumental activities of daily living	Interventions: Progressive, competency-based conditioning exercises of the arms and legs with resistant elastic bands; balance exercises Control: Educational program	● 5 self-reported IADL, including shopping for groceries, meal preparation, housework, laundry, and getting to places beyond walking distance ● Mobility: timed rapid gait and timed chair stands; modified POMA ● Integrated physical performance: modified PPT	Compared to the educational control group, intervention group had reductions in IADL disability of 17.7% at 7 months (P=.036) and 12.0% at 12 months (P=.143) and had gains, ranging from 7.2% to 15.6%, in mobility and integrated physical performance at 7 and 12 months.
● Liu-Ambrose et al., 2004 ● 98 women aged 75–85 years (mean=79)	● Fall risk: postural stability, dominant quadriceps strength, dominant hand	Interventions: a. Resistance training group: with the aims of increasing muscle	● Fall risk: PPA ● Posture stability test ● Gait speed test ● General physical	Both resistance training and agility training significantly improved balance confidence by 6%

with low bone mass ● 13-week intervention	reaction time, joint position sense, and edge contrast sensitivity ● Gait speed: walking ● General physical function: balance and mobility ● Balance confidence	strength in the extremities and trunk; b. Agility training group: with the aims of increasing hand-eye and foot-eye coordination, dynamic and static balance, and psychomotor performance (reaction time) Control: Stretching class consisted of stretching exercises, deep breathing and relaxation techniques, and general posture education.	function: CB&M ● Balance confidence: ABC ● Physical activity level: PASE	from baseline after 13 weeks. However, the change in balance confidence was only weakly correlated with improved general physical function and not significantly correlated with the changes in fall risk score, postural stability, gait speed, or physical activity level.
● Liu-Ambrose et al., 2005 ● 98 women aged 75–85 years (mean=79) with low bone mass	● Back pain and its related disabilities ● Health-related quality of life	Interventions: a. Resistance training group: with the aims of increasing muscle strength in the	● Back pain intensity and its related disabilities: ODQ ● Health-related qualify of life: QUALEFFO	Back pain and its related disabilities significantly improved within each of the three experimental groups. Specifically, agility

● 25-week intervention		extremities (upper and lower) and trunk; b. Agility training group: with the aims of increasing coordination, balance, and psychomotor performance (reaction time) Control: Stretching class consisted of general stretching and relaxation techniques.		training improved back pain and its related disabilities by 32% (P=0.05), resistance training by 27% (P=0.01) and stretching by 21% (P=0.05). However, only resistance training and agility training significantly enhanced health-related quality of life.
● Elley et al., 2008 ● 312 community-living people (aged ≥75, mean=80.8) who had fallen in the previous year ● 12-month intervention	● Muscle strength and balance ● Ability to perform instrumental activities of daily living	Interventions: Home-based nurse assessment of falls-and-fracture risk factors and home hazards, referral to appropriate community interventions, and strength and balance	● Muscle strength and balance: TUG, 30-second chair stand test, four-test balance scale, and 7.5-cm block step test) ● Fear of falling: MFES	This nurse-led intervention was not effective in reducing falls in older people who had fallen previously. Implementation and adherence to the fall-prevention measures

		exercise program. Control: Usual care and social visits	● Activities of daily living: NEADL ● Level of physical activity: AHSPAQ ● Quality of life: SF36	was dependent on referral to other health professionals working in their usual clinical practice. This may have limited the effectiveness of the interventions.
● Kim et al., 2013 ● 150 women (aged ≥75, mean=80.5) with knee pain ● 3-month intervention	● Knee pain ● Functional mobility ● Muscle strength	Interventions: a. Exercise (Ex) group: Group-based 60-min exercise class focusing on strengthening of the muscles around the knee such as the quadriceps and hamstrings, as well as the tibialis anterior, gastrocnemius and soleus; b. Heat/steam generating sheet (HSGS) group: The participants were asked to place on the	● Degree of pain: VAS ● Pain and stiffness in the knees: JKOM ● Physical mobility, balance, gait speed, and functional ability: TUG	The results showed VAS improvements in the Ex + HSGS and HSGS groups. Total JKOM score, muscle strength, and functional mobility significantly improved in the Ex + HSGS group compared with the HE group. The odds ratio (OR) for VAS and functional mobility improvement was more than eight times as great in the Ex + HSGS group (OR = 8.60, 95% confidence interval (CI) =

		painful knee for 6 h a day immediately after waking up, and if they had pain in both knees they were asked to place the HSGS on the most painful knee; c. Ex+HSGS group: A combination of the same intervention as the EX and HSGS group. Control: Educational classes focused on nutrition, cognitive function, and oral hygiene.		2.82–32.73) compared with the education group. Ex or HSGS alone were insufficient in enhancing functional fitness or improving pain and quality of life. The combined effects of both Ex and heat therapy seems to have an added benefit of decreasing pain, improving physical function and increasing quality of life.
• El-Khoury et al., 2015 • 706 women aged 75-85 (mean=79.7), living in their own home, and with diminished balance	• Balance and gait capacities	Intervention: Exercises were designed to improve postural stability (assessed by body sway), muscle extensibility and to a lesser degree joint	• Rates of all falls • Physical functional capacities: balance and motor function test • Fear of falling: FES-I	Women in the intervention group performed significantly better on all physical tests and had significantly better perception of their

and gait capacities (assessed by the time they took to walk a 6-meter course and the tandem walk test. ● 2-year intervention		flexibility (for example, hip flexor and calf stretches), balance (for example, knee bends, tandem stance, backward walking, sit to stand), reaction time (for example, play in group with a ball), coordination (for example, side leg swings, front leg swings), muscle strength critical for posture and balance (for example, hip abductor, knee extensor, ankle plantar-flexors), and internal sense of spatial orientation (senses of position and movement of limbs and trunk). Control: Educational program	● Physical activity level: casual walking, walking for exercise, and total leisure physical activities ● Perceived health related quality of life: SF36	overall physical function than women in the control group.
● Lihavainen et al, 2011	● Mobility limitation	Interventions: The	● Mobility limitation:	The treatment effect of

• 781 persons aged 75-98 years (mean=81.1) with persistent musculoskeletal pain • 2-year intervention	• Persistent musculoskeletal pain.	intervention, which consisted of a medical and a physical activity component, was based on the comprehensive geriatric assessment and multidisciplinary team approach. Group-based progressive resistance training was offered to the intervention group once a week, the objective was to increase mobility, and the emphasis was on the lower limbs. The training included leg press, leg extension, leg curl, hip abduction, hip adduction, hip extension and abdominal crunch. Control: did not receive any intervention.	self-reported difficulties in walking • Persistent musculoskeletal pain: questions ascertaining pain in the shoulders, neck, back, hips, knees or other sites in the upper or lower body • Level of physical activity: modified version of the scale by Grimby • Depressive symptoms: 15-item GDS • Cognitive function: MMSE	the intervention on mobility was significant (OR 0.75, 95% CI 0.59–0.96) at the end of the two-year intervention among persons with pain. The effect remained significant (OR 0.79, 95% CI 0.67–0.93) when the one-year post-intervention follow-up was taken into account,

• Tikkanen et al., 2013 • 559 community-dwelling participants aged ≥75 (mean=80.6). They were further categorized as inactive or active men or women according to their physical activity level. • 2-year intervention	• Chair rise capacity: lower extremity muscle power and postural control • Ability to perform instrumental activities of daily living	Intervention: All the participants of the intervention group received individually targeted physical activity counseling annually and had an opportunity to participate in supervised strength (lower extremities) and balance training once a week. Control: did not receive any interventions	• Level of Physical activity: modified Grimby scale • Chair rise capacity: timed chair rise test • Comorbidity: modified version of the FCI • Cognitive function: MMSE • 8-item IADL scale	The intervention improved the chair rise capacity in physically active women (adjusted mean difference –1.67 s, 95% confidence interval –3.21 to –0.13, p = 0.02). There was no improvement in inactive women or in men, regardless of their physical activity level.
• Kim et al., 2012 • 155 women aged ≥75 (mean=79.1) identified with sarcopenic obesity • 3-month intervention	• Sarcopenia (loss of skeletal muscle mass and strength)	Interventions: a. Exercises group: muscle strength training, including chair exercise (e.g. toe raises, heel raises, knee lifts, knee extensions, hip flexions, and lateral leg	• Body composition: segmental multifrequency bioelectrical impedance analysis instrument • Calf girth and functional fitness variables (e.g.	This study demonstrated walking speed significantly increased in all three intervention groups, leg muscle mass in the exercise + AAS and exercise groups, and knee extension strength only in the exercise + AAS group

		raises); ankle-weight exercise (to strengthen lower extremities); resistance band exercise (to strengthen the upper and lower body); balance and gait training (improvement of static, dynamic, and lateral balancing ability); b. Amino Acid Supplementation (AAS) group: Packets of powdered amino acid supplements were provided for the participants to be taken with water or milk, two times a day every day for 3 months; c. Exercise+AAS group: A	walking speeds and knee extension strength): FFT	(9.3% increase, P = .01). The odds ratio for leg muscle mass and knee extension strength improvement was more than four times as great in the exercise + AAS group (odds ratio = 4.89, 95% confidence interval = 1.89– 11.27) as in the control group.

		combination of the same intervention as the exercise and AAS group. Control: educational program		
• Kim et al., 2015 • 131 frail women aged ≥75 (mean=80.85) • 3-month intervention	• Frailty, which includes weight loss, muscle weakness, exhaustion, slow walking speed, and low physical activity level	Interventions: a. Milk fat globule membrane (MFGM) supplementation group: the MFGM group was provided with supplements in pill form, every 2 weeks; b. Exercises+MFGM group: strengthening exercises including chair exercise, resistance band exercise, and balance and gait training.	• Frailty status: interview surveys, body composition assessments using dual-energy x-ray absorptiometry (DXA; Hologic QDR 4500A, USA), and physical function tests (grip strength, isometric knee extension strength, walking speed)	Frailty reversal rate was significantly higher in the Ex+MFGM (57.6%) than in the MFGM (28.1%) or placebo (30.3%) groups at post-intervention ($\chi2$ = 8.827, P = 0.032), and at the follow-up was also significantly greater in the Ex+MFGM (45.5%) and Ex+Plac (39.4%) groups compared with the placebo (15.2%) group ($\chi2$ = 8.607, P = 0.035). The exercise+MFGM group had the highest odds ratio

		MFGM were provided for this group; c. Exercises+placebo group: A combination of the same intervention as the exercise and placebo group. Control (Placebo): The placebo group followed the same protocol as the MFGM supplementation group; however, pill included whole milk powder instead of MFGM.		(OR) for frailty reversal at post-intervention and follow-up (OR = 3.12, 95% confidence interval (CI) = 1.13–8.60; and OR = 4.67, 95% CI = 1.45–15.08, respectively).
• Kim et al., 2013 • 128 women aged over 75 years (mean=80.2) were defined as sarcopenic • 3-month intervention	• Muscle mass, strength and walking ability in sarcopenic women	Interventions: a. Exercise group: the exercise consisted of stretching, muscle strengthening, balance and gait training of moderate intensity;	The performance measures included muscular strength (grip strength, knee extension strength), walking ability (usual and maximum walking speed, and timed	There were significant group X time interactions observed in timed up & go ($P < 0.001$), usual walking speed ($P = 0.007$) and maximum walking speed ($P < 0.001$). The exercise +

		b. Tea catechin (TC) supplementation group: Bottles containing 350 mL of tea fortified with 540 mg of catechin were provided for the participants in the TC supplementation group every 2 weeks; c. Exercise+TC group: A combination of the same intervention as the exercise and TC group. Control: health educational program	up & go [TUG]) and balance ability (one leg standing time with eyes open).	catechin group showed a significant effect (odds ratio 3.61, 95% confidence interval 1.05–13.66) for changes in the combined variables of leg muscle mass and usual walking speed compared with the health education group.
• Hauer, 2001 • 57 female geriatric patients (mean age 82±4.8 years; range 75–90) admitted to	• Fall: strength, mobility, and balance • Muscle function: muscle strength of leg extension, knee	Intervention: The patients underwent a regimen of high-intensity progressive resistance training of functionally relevant	• Medical status, comorbidity, medication, and functional status: ADL and IADL	The patients in the intervention group increased strength, functional motor performance, and balance

acute care or inpatient rehabilitation with a history of recurrent or injurious falls including patients with acute fall-related fracture. ● 3-month intervention	extension, knee flexion, ankle plantar flexion, and handgrip strength ● Motor performance such as walking, stepping, standing up, balance performance, and complex performance ● Ability to perform activities and instrumental activities of daily living.	muscle groups, including Knee and hip extensions, hip abduction and extension, ankle plantar flexion, and bilateral plantar flexion. Participants were trained in basic functions such as walking, stepping, and sitting to modify unsafe or inefficient performance. Balance training was performed in static and dynamic positions. Group games, basic forms of dance, and basic forms of tai chi were used when patients' performance would allow it. Control: motor placebo activities including flexibility exercise,	● Maximal dynamic concentric muscle strength in hip and knee extensors: One-Repetition-Maximum ● More-complex motor function: TUG ● Motor deficits: POMA ● Balance: FRT and modified test battery ● Cognitive status: MMSE	significantly. Fall-related behavioral and emotional restrictions were reduced significantly. Improvements persisted during the 3-month follow- up with only moderate losses. Fall incidence was reduced non-significantly by 25% in the intervention group compared with the control group (RR:0.753 CI:0.455–1.245).

		calisthenics, ball games, and memory tasks while seated.		
• Aartolahti et al., 2015 • 182 community-dwelling individuals (aged 75–98 years, mean=79.7) • The total length of training was 2.3 years but the number of offered training sessions per participant varied from 94 to 104	• Balance and mobility • Grip Strength • Maximal isometric knee extension strength • Ability to perform instrumental activities of daily living	Intervention: Strength and balance training (SBT). Progressive strength training included knee extension and flexion, leg press, hip adduction, abduction and extension, and abdominal crunch with gym equipment. Training was offered once a week for 2.3 years. Adherence was defined as the proportion of attended sessions relative to offered sessions. Participants were classified based on their adherence level into low (≤33.3%), moderate (33.4–66.5%) and high (≥66.6%)	• Balance and basic mobility skills: BBS and TUG • Grip Strength: Seahan dynamometer • Maximal isometric knee extension strength: adjustable dynamometer chair • Ability to perform instrumental activities of daily living: IADL • Level of physical activity: modified Grimby scale • Cognitive function: MMSE • Depressive	High adherence was predicted by female sex; younger age; better cognition; independence in Instrumental Activities of Daily Living; higher knee extension strength; faster walking speed; and better performance on the Berg Balance Scale and Timed Up and Go tests. Poorer self-perceived health and the use of a walking aid were related to low adherence. The findings showed that long-term continuation of training is possible for older community-dwelling

		adherers.	symptoms: 15-item GDS	adults, although poorer health and functional limitations affect training adherence.
• Helbostad, 2004 • 77 persons aged 75 years and older (mean 81, SD4.5), living at home • 12-week intervention	• Walking • Balance • Muscle strength	Intervention: a. Home training (HT) group: four non-progressive exercises, aimed at improving functional aspects of balance and strength were used, there was no contact between the participants of the group and physical therapists; b. Combined training (CT) group: there were 5 to 8 participants in each of subgroups, and each training class was run by one physical	• Walking and functional tasks: walking speed, sit-to-stand, timed pick-up, maximum step length, and TUG • Isometric muscle strength: digital dynamometer • Postural sway: trunk accelerometer fixed to the lower back	Daily home exercises supervised by physical therapists were effective in improving functional abilities, and that supplementary individualized group exercises did not have an additional effects.

		therapist. Subjects in the CT group were instructed to do the same hone exercises and at the same intensity as the HT group.		

ABC=Activities-Specific Balance Confidence Scale;
ADL= Barthel/Mahoney Activities of Daily Living Index;
AHSPAQ=Auckland Heart Study physical activity questionnaire;
BBS=Berg Balance Scale;
CB&M= Community Balance and Mobility Scale;
FCI= functional comorbidity index;
FES-I=Falls Efficacy Scale-International;
FFT= Functional Fitness Test;
FRT=Functional Reach Test;
GDS= Geriatric Depression Scale;
IADL= Lawton/Brody Instrumental Activities of Daily Living Index;
JKOM=Japanese knee osteoarthritis measure;
MFES=Modified Falls Efficacy Scale;
MMSE=Mini-Mental State Examination;
NEADL=Nottingham Extended Activities of Daily Living;
PASE=Physical Activities Scale for the Elderly;

PPT=Physical Performance Test;

POMA=Performance Oriented Mobility Assessment;

QUALEFFO=Quality of life questionnaire of the European Foundation for Osteoporosis;

SF36= Medical Outcomes Study 36-item Short Form Questionnaire;

TUG=Timed Up & Go;

VAS=Visual Analog Scale;