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Health benefits of multicomponent training programmes in seniors: a systematic review

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SUMMARY

Background: The ageing process is intrinsically associated with decline in physical endurance, muscle strength and gait ability and balance, which all contribute to functional disability. Regular physical training, and more particularly multicomponent training (MCT), has demonstrated many health benefits. **Objective:** To evaluate the evidence of the health benefits of MCT including endurance training, muscle strengthening, balance exercises, and/or stretching (i.e. flexibility training) and/or coordination training in adults aged 65 years or over. **Methods:** A comprehensive, systematic database search for manuscripts was performed in CINAHL Plus, Embase, Medline, PubMed Central, ScienceDirect, Scopus, Sport Discus and Web of Science using key words. For potential inclusion, two reviewers independently assessed all intervention studies published in English language from 1 January 2000 to 30 April 2015. **Results:** Of 2525 articles initially identified, 27 studies were finally included in this systematic review. They were all divided into five categories according to their main outcome measurements (cardio-respiratory fitness, metabolic outcomes, functional and cognitive functions and quality of life, QoL). These studies reported that MCT has a significant beneficial effect on cardio-respiratory fitness and on metabolic outcomes. Substantial improvement in functional and cognitive performance was also measured and a slighter but positive effect on QoL. **Conclusion:** Overall, this review demonstrates a positive effect of MCT with functional benefits and positive health outcomes for seniors. Based on this evidence, clinicians should encourage all adults aged 65 or over to engage in MCT programmes to favour healthy ageing and keeping older members of our society autonomous and independent.

Review criteria

- This systematic review was conducted in eight electronic databases with research by key words.
- 2525 articles published from 1 January 2000 to 30 April 2015 have been selected by two independent readers.
- 27 articles meeting our inclusion criteria (19 randomised and 8 non-randomised controlled trials conducted in adults aged 65 or over) were considered in the review

Message for the clinic

- This review highlights the benefits of multicomponent training (MCT) on seniors' health.
- Multicomponent training has a significant impact on cardio-respiratory fitness, metabolic outcomes and induces substantial improvement on functional and cognitive performance and quality of life.
- Thus, physicians should be convinced to encourage seniors to engage in MCT to favour healthy ageing and keep them autonomous and independent.

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None of the above listed authors has any conflict of interest to declare for this manuscript.

Introduction

The world's population is ageing steadily. The United Nations have coined the term 'demographic transition' to describe how declines in both mortality and fertility have lead us to this point, which is without parallel in human history (1). Over the last 50 years the number of individual older than 65 years has tripled; and by 2025–2030, this population will be growing 3.5 times as rapidly as the total population (1). While the ageing of the general population is one of humanity's greatest triumphs, it also confronts societies with enormous medical challenges (2). We cannot escape that lengthening lifespan is not necessarily synonymous with extending life expectancy in good health. The progressive decline with in a disability-free life is associated with an increase in the requirement for assisted living amongst older individuals in order for them to perform basic activities of daily living (3,4).

It is widely known that the regular practice of physical activity may have many health benefits for people including older ones. It would contribute to a healthy and an independent lifestyle, enhancements in functional capacities and improvement of quality of life (QoL) (5,6). However, sedentary lifestyle is highly prevalent in seniors (i.e. aged 65 years or over). According to recent reports, the participation rate in sportive recreational activities is very low in that population (7), and few of them follow the recommendations edited by the American College of Sports Medicine which stress aerobic activities taking into account the older adult's aerobic fitness, activities that maintain or increase flexibility and balance exercises for older adults at risk of falls (8). Physician should normally offer seniors an activity plan for achieving recommended physical activity that integrates preventive and therapeutic recommendations (8).

The promotion of physical activity in seniors should emphasise moderate-intensity aerobic activity, muscle-strengthening activity, reducing sedentary behaviour and risk management. Indeed, some previous investigations have reported that regular multimodal or multicomponent training (MCT) based on combined endurance and muscle strength training could minimise the physiological effects of an otherwise sedentary lifestyle by reducing the development and progression of chronic diseases and disabling conditions (9,10). A number of recommendations underline the importance of MCT in improving health and physical function among older frail patients through endurance and strength training combined with balance exercises, and/or flexibility and/or coordination training (11–14).

To the best of our knowledge, most of available systematic reviews specifically dedicated to older population have mainly evaluated the benefits of unimodal exercise (15–17). Only one report has reviewed the potential benefits of MCT (10) by including 15 randomised controlled trials (RCT) totalling 2149 subjects (mean cohort age ranging from 67 $\pm$ 8 to 84 $\pm$ 3 years). The authors concluded that MCT had a positive effect on falls prevention, and the limited data available suggested a small effect on physical, functional and QoL outcomes.

Finally evidence that simultaneously prescribed doses and intensities of strength, aerobic and balance training in seniors are both feasible and capable of eliciting beneficial changes in physical function and QoL is still lacking. We present the result of a systematic review assessing the potential health benefits of MCT for adults aged 65 years or over.

Methods

Criteria for study inclusion/exclusion

Based on the title of the article and available abstracts, the reports were first evaluated for inclusion in the review using the following criteria.

Article type and study design

Original research papers about observational and intervention studies (randomised controlled trial – RCT or not) published in peer-reviewed journals were considered for inclusion. In addition, only full articles limited to the English language were extracted.

Population

Studies that involved senior cohorts aged 65 or over were included. Studies with younger cohorts or that had a single clinical diagnosis as an entry criterion (e.g. stroke, multiple sclerosis) were not considered.

Interventions

The intervention must have been multi-modal or MCT, comprised of endurance/aerobic, strength/resistance training and balance/stability, and/or flexibility, and/or coordination training. The rational for the selective inclusion of aerobic/endurance, strength/resistance and balance/stability training was that for all these modalities positive effects on health outcomes have been demonstrated (10,18). Endurance/aerobic training was defined as any exercise involving movement of large muscle groups for a period of time (e.g. walking, cycling, or rowing). Strength/resistance training was considered as training progressive in nature and defined as involving an increase in load across the training period without any specific intensity. Balance/stability training included any training that sought increases in the subject's ability to maintain balance in the face of a threat to stability (e.g. specific balance exercises or Tai Chi).

Search strategy

A comprehensive, systematic database search for manuscripts was performed on September 2015 using CINAHL Plus, Embase, Medline, PubMed Central, ScienceDirect, Scopus, Sport Discus and Web of Science) electronic databases from 1 January 2000 to 30 April 2015.

Four categorical searches were conducted using the following keywords: (i) multi-modal exercise, or MCT exercise, (ii) exercise group, endurance or aerobic training, strength or resistance training, balance or stability and flexibility or coordination, (iii) cardiovascular, lipid profile, cognitive, functional fitness, frailty or fall, (iv) community-dwelling, frail older adults/patients, elderly, much older/elderly, aged, ageing, oldest or old. All titles were manually searched for potential inclusion. Reference lists of articles retrieved, review articles and position stands were examined for further relevant references.

Quality assessment

Once studies were collected based on a minimum quality threshold, defined as having met all inclusion criteria (i.e. exclusion of studies that did not match the topic and/or meet inclusion; duplicate studies or no data for MCT), a more detailed assessment of the study quality was conducted. Thus, additional articles were excluded because their outcomes were based only on the combination of endurance and resistance training, the combination of resistance training and balance and flexibility training without including endurance training, home-based programmes unsupervised by a personal trainer throughout the training period, and studies evaluating MCT in adults < 65 years of age (Figure 1).

Data extraction and synthesis

Two reviewers (WB and ES) independently assessed studies for potential inclusion. Briefly, studies were extracted according to author, year of publication, mean age of the study sample, study design and outcomes for physical and/or functional performance as well as health and QoL. Thus selected studies were then divided into five groups according to the five major outcomes. This systematic review aimed to assess: cardio-respiratory fitness (Table 1), metabolic outcomes (Table 2), functional status (Table 3), cognitive performance (Table 4) and QoL (Table 5).

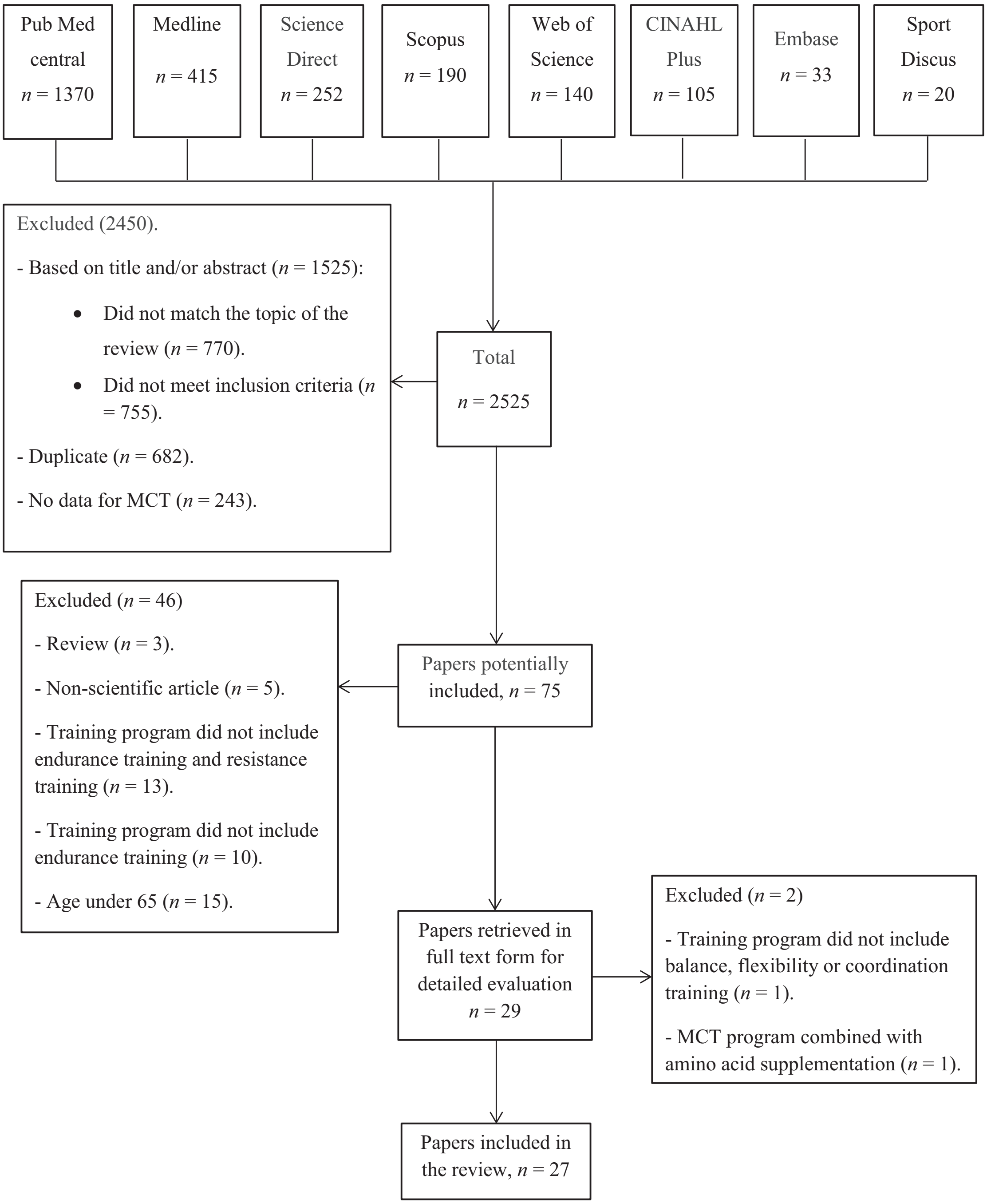

Figure 1 Flow chart of the literature search

Results

Study inclusion/exclusion

The process of study inclusion/exclusion at each step is depicted by Figure 1. Briefly, the search strategy yielded 2525 articles. Because their outcomes were based on the combination of endurance and resistance training; resistance training and balance and flexibility training without including endurance training; or unsupervised home-based programmes, 2450 articles were immediately excluded. Finally, the review included 27 studies satisfying all inclusion criteria and threshold of quality [19 RCTs (19–37) and 8 non-RCTs (38–45)].

Interventions (MCT)

The review has notified the heterogeneity between studies in terms of MCT protocols. Five different programmes were considered with the combination of endurance, strength, balance and flexibility training as the most frequently considered (22,23,26,27,29,31,32,38,39,43–45). The combination of endurance training, strength and balance training was analysed in nine studies (24,25,30,33,35–37,40,42). The benefits to combine endurance, strength, balance, flexibility and coordination training was analysed in three RCTs (21,28,34); two RCTs (19,20) considered the combination of endurance, strength and flexibility training. Finally, one study reported MCT as the combination of endurance, strength, balance and coordination training (41).

Effects of MCT on cardio-respiratory fitness

The results are summarised in Table 1 [1 RCT (21) and two non-RCTs (38,39)]. The peak volume of oxygen (VO_{2peak}) was the outcome measure the most commonly considered and assessed during a graded treadmill-walking test. In one study (21), the VO_{2peak} was reported as significantly improved compared with the control group; and in 2 studies when VO_{2peak} values were compared with baseline (VO_{2peak} gain ranging from 10.0% to 20.0%).

Effects of MCT on metabolic outcomes

Body composition

The impact of MCT on body mass and its composition was reported by nine studies (19,20,22–24,38–41) (Table 2). The total body weight was considered as an outcome in one RCT (22) and three non-RCTs (38,39,41); and only one non-RCT showed significant 3.2% reduction (41). The body mass index was reported in all nine studies among which 3 [1 RCT (19) and two non-RCT (40,41)] found a significant decrease ranging from 1.0% to 3.4%. More specifically, the body composition was assessed in six studies by using bioelectrical impedance analysis (19,20,23,24,40,41) and in 3, with dual energy X-ray absorptiometry (DEXA) analysis (22,38,39). When the percentage of fat mass was considered (22,38,39,41), two non-RCTs studies reported a significant decrease [3.6% (39); 2.4% (41)]. Furthermore, fat mass and fat-free mass were analysed as outcomes measures in three non-RCTs (38–40) and 1 RCT (22). A significant reduction of fat mass was measured (ranging from 3.0% to 4.0%) combined with a significant gain of fat-free mass (ranging from 1.8% to 2.6%) in three studies (22,38,39).

Lipid profile

One RCT (23) and one non-RCT (40) investigated the blood lipid profile (Table 2). Whilst both studies reported a significant reduction in triglycerides and high-density lipoprotein serum levels (changes ranging from 6.0% to 8.2%), none showed significant changes in total cholesterol or low-density lipoprotein level.

Table 1 Summary of studies that analyse the effects of MCT on cardio-respiratory fitness

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Binder et al. (21)	RCT	83.0 ± 4.0	ET, ST, BT, FT, CT 3 sessions/wk, 36 wks	VO_{2peak}	A
Smith et al. (38)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT 90 min/session 3 sessions/wk, 12 wks	VO_{2peak}	A
Villareal et al. (39)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT 90 min/session 3 sessions/wk, 10 wks	VO_{2peak}	A

SD, standard deviation; RCT, randomised controlled study; A, positive result (beneficial impact of MCT); VO_{2peak}, peak oxygen uptake; ET, endurance training; ST, strength training; BT, balance training; FT, flexibility training; CT, coordination training; wk, week.

Table 2 Summary of studies that analyse the effects of MCT on metabolic outcomes

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Toraman et al. (19)	RCT	74.0 ± 3.7	ET, ST, FT: 70 min/session	*Body composition*	
			3 sessions/wk, 9 wks	BMI	A
Carvalho et al. (40)	Non-RCT	68.5 ± 5.1	ET, ST, BT	*Body composition*	
			60 min/session	BMI	A
			3 sessions/week, 32 wks	FFM, FM	B
				Lipid profile	
				Triglyceride	A
				HDL-C	B
				TC, LDL-C	B
Smith et al. (38)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT	*Body composition*	
			90 min/session	FM	A
			3 sessions/wk, 12 wks	FFM	A
				Body weight, BMI	B
Carvalho et al. (24)	RCT	69.0 ± 3.5	ET, ST, BT	*Body composition*	
			60 min/session	BMI	B
			3 sessions/wk, 32 wks		
Toraman et al. (20)	RCT	72.4 ± 6.7	ET, ST, FT	*Body composition*	
			70 min/session	BMI, % of FM	B
			3 sessions/wk, 9 wks		
Villareal et al. (39)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT	*Body composition*	
			90 min/session	FM	A
			3 sessions/wk, 10 wks	% of FM	A
				FFM	A
				Body weight, BMI	B
Nakamura et al. (41)	Non-RCT	67.8 ± 4.6	ET, ST, BT, CT	*Body composition*	
			90 min/session	Body weight	A
			3 sessions/wk, 12 wks	% of FM	A
				BMI	A
Lambert et al. (22)	RCT	69.0 ± 1.0	ET, ST, BT, FT	*Body composition*	
			90 min/session	FFM	A
			3 sessions/wk, 12 wks	FM	A
				Body weight, BMI	B
Marques et al. (23)	RCT	68.3 ± 3.8	ET, ST, BT, FT	*Body composition*	
			60 min/session	BMI, % of FM	B
			2 sessions/wk, 32 wks	*Lipid profile*	
				Triglyceride	A
				HDL-C	B
				TC, LDL-C	B

SD, standard deviation; RCT, randomised controlled study; A, positive result (beneficial impact of MCT); B, neutral result (no effect of MCT); ET, endurance training; ST, strength training; BT, balance training; FT, flexibility training; CT, coordination training; BMI, body mass index; FFM, fat-free mass; FM, fat mass; TC, total cholesterol; HDL-C, high-density lipoprotein; LDL-C, low-density lipoprotein; wk, week.

Effects of MCT on functional status

Muscle strength

The impacts of MCT on muscle strength were evaluated in 13 RCTs (19–22,24–27,29,30,32,33,35) and seven non-RCTs (38,39,41–45) (Table 3). Both upper and lower extremity strength were analysed in 10 studies (19,20,22,24,26,38,39,41,42,44) whereas 10 assessed either upper (27,43) or lower (21,25,28,30,32,33,35,45) limbs.

Muscle strength was measured using either the one-repetition-maximum test (1-RM) (19,20,22,27,38,39,43,44), the 30 s chair stand test 6 (19,20,24,25,41,44); the arm curl test (19,20,24,42–44); the chair rise test (30,32,33,45); the maximum isometric contractions (26,29,35); the hand-grip strength test (26,41,42); and an isokinetic dynamometry (21,25). Significant improvement as a result of MCT was measured in the training group compared with controls in five RCTs

Table 3 Summary of studies that analyse the effects of MCT on functional status

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Barnett et al. (35)	RCT	74.9 ± 5.4	ET, ST, BT: 60 min/session	*Functional fitness*	
			4 session/wk, 24 wks	PSEO	A
				PSEC	A
				Coordinated stability	A
				Muscle strength	
				Knee and ankle	B
				Risk of falling	A
Taguchi et al. (26)	RCT	NM	ET, ST, BT, FT	*Functional fitness*	
		Age range: 74–96	90 min/session	Sit and reach test	A
			1 session/wk, 48 wks	Walking speed	A
				Stride length	A
				6MWT	A
				One-leg stance	B
				Muscle strength	
				Lower limb	A
				Risk of falling	A
Lord et al. (29)	RCT	79.5 ± 6.4	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	6MWT	A
			2 sessions/wk	Postural sway test	B
			48 wks	*Muscle strength*	
				Knee extension of quadriceps	B
				Risk of falling	A
Ansai et al. (33)	RCT	82.4 ± 2.4	ET, ST, BT	*Functional fitness*	
			60 min/session	One-leg stance test	A
			3 sessions/wk, 16 wks	TUG, tandem test	B
				Muscle strength	
				Chair rise test	A
				Risk of falling	B
Kovacs et al. (31)	RCT	77.8 ± 11.1	ET, ST, BT, FT	*Functional fitness*	
			90 min/session	POMA-B	A
			2 sessions/wk, 48 wks	POMA-G	A
				TUG	A
				Risk of falling	B

Table 3 Continued

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Toraman et al. (19)	RCT	74.0 ± 3.7	ET, ST, FT 70 min/session	*Functional fitness*	
			3 sessions/wk, 9 wks	8 foot up and go	A
				6MWT	A
				Back scratch	A
				Chair sit and reach	A
				Muscle strength	
				Arm curl	A
				30 s chair stand	A
Marques et al. (23)	RCT	68.3 ± 3.8	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	6MWT	A
			2 sessions/wk, 32 wks		
Rubenstein et al. (25)	RCT	74.9 ± 5.4	ET, ST, BT	*Functional fitness*	
			90 min/session	6MWT	A
			3 sessions/week, 12 wks	One-leg balance dominant leg and non-dominant leg	A
				Muscle strength	
				Left and right knee extension	A
				Left and right knee flexion	A
				Right hip extension and flexion	A
				Right and left ankle plantar flexion	A
				Sit-to-stand test	A
Binder et al. (21)	RCT	83.0 ± 4.0	ET, ST, BT, FT, CT	*Functional fitness*	
			3 session/wk, 36 wks	One-leg stance test	A
				Berg balance scale	A
				Muscle strength	
				MVC of knee extensor torque	A
				MVC of knee flexor torque	A
Toraman et al. (20)	RCT	72.4 ± 6.7	ET, ST, FT	*Functional fitness*	
			70 min/session	8 foot up and go test	A
			3 sessions/wk	6MWT	A
			9 wks	Back scratch	B
				Muscle strength	
				Arm curl	A
				30 s chair stand	A

Table 3 Continued

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Freiberger et al. (30)	RCT	76.1 ± 4.1	ET, ST, BT	*Functional fitness*	
			60 min/session	TUG	A
			3 sessions/wk, 16 wks	*Muscle strength*	
				Chair rise test	A
Toto et al. (44)	Non-RCT	78.1 ± 8.0	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	Chair sit and reach	A
			2 sessions/wk, 10 wks	Back scratch	A
				8 foot up and go	A
				Muscle strength	
				Arm curl	A
				30 s chair stand	A
Villareal et al. (39)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT	*Functional fitness*	
			90 min/session	Walking speed	A
			3 sessions/wk, 10 wks	One-leg stance test	A
				Muscle strength	
				Bench and leg press	A
				Knee flexion and extension	A
				Seated row	A
				Biceps curl	A
				Chair rise test	A
Shubert et al. (38)	Non-RCT	79.6 ± 6.8	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	TUG, tandem test, one leg stance	B
			2 sessions/wk, 48 wks	*Muscle strength*	
				Chair rise test	A
Carvalho et al. (40)	Non-RCT	68.5 ± 5.1	ET, ST, BT	*Functional fitness*	
			60 min/session	6MWT	A
			3 sessions/wk, 32 wks		
Levy et al. (43)	Non-RCT	67.0 ± 12.0	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	Back scratch	A
			2 sessions/wk, 12 wks	8 foot up and go	A
				6MWT	A
				Muscle strength	
				Arm curl	A

Table 3 Continued

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Smith et al. (38)	Non-RCT	70.0 ± 2.0	ET, ST, BT, FT	*Muscle strength*	
			90 min/session	Bench press	A
			3 sessions/week, 12 wks	Leg press	A
				Knee extension	A
				Knee flexion	A
				Seated row	A
King et al. (32)	RCT	77.0 ± 4.5	ET, ST, BT, FT	*Functional fitness*	
			75 min/session	Tandem test	A
			2 sessions/wk, 48 wks	6MWT	B
				8 m fast	B
				8 m usual gait	B
				Muscle strength	
				Chair rise test	B
Carvalho et al. (24)	RCT	69.0 ± 3.5	ET, ST, BT	*Functional fitness*	
			60 min/session	Chair sit and reach	A
			3 sessions/wk, 32 wks	Back scratch	A
				8 foot up and go	A
				6MWT	B
				Muscle strength	
				Arm curl	A
				30 s chair stand	A
Nakamura et al. (41)	Non-RCT	67.8 ± 4.6	ET, ST, BT, CT	*Functional fitness*	
			90 min/session	6MWT	A
			3 sessions/wk, 12 wks	Functional reach	A
				Muscle strength	
				Sit and stand test	A
				Grip test	A
Lambert et al. (22)	RCT	69.0 ± 1.0	ET, ST, BT, FT	*Muscle strength*	
			90 min/session	Biceps curl	A
			3 sessions/wk, 12 wks	Bench press	A
				Seated row	A
				Knee flexion	A

Table 3 Continued

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
				Knee extension	A
				Leg press	A
Justine et al. (42)	Non-RCT	70.9 ± 7.8	ET, ST, BT	*Functional fitness*	
			60 min/session	6MWT	A
			3 sessions/wk, 12 wks	Functional reach	A
				TUG	A
				Chair sit-and-reach	B
				Back scratch	B
				Muscle strength	
				Right and left arm curl	A
				Right and left handgrip	A
				Lower limb	A
Worm et al. (27)	RCT	81.2 ± 4.2	ET, ST, BT, FT	*Functional fitness*	
			60 min/session	10-m walking time	A
			2 session/wk, 12 wks	Maximal walking speed	A
				Berg balance scale	A
				Muscle strength	
				Right shoulders abductors	A
				Left shoulders abductors	A
				MVC of right hand side	A
				MVC of left hand side	A
Means et al. (28)	RCT	NM	ET, ST, BT, FT, CT	*Risk of falling*	A
		Age over 65	90 min/session		
			3 sessions/wk, 6 wks		
Vaughan et al. (34)	RCT	NM	ET, ST, BT, FT, CT	*Functional fitness*	
		Age range: 65–75	60 min/session	6MWT	A
			2 sessions/wk, 16 wks	One-leg stance test	A
				TUG	A

SD, standard deviation; RCT, randomised controlled study; A, positive result (beneficial impact of MCT); B, neutral result (no effect of MCT); ET, endurance training; ST, strength Training; BT, balance training; FT, flexibility training; CT, coordination training; PSEO, postural sway with eyes opened; PSEC, postural sway with eyes closed; 6MWT, 6 min walking test; TUG, time up and go test; POMA-B, Performance Oriented Mobility Assessment balance score; POMA-G, Performance Oriented Mobility Assessment gait score; MVC, maximum voluntary contraction; NM, not mentioned; wk, week.

Table 4 Summary of studies that analyse the effects of MCT on cognition performance

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Suzuki et al. (36)	RCT	76.0 ± 7.1	ET, ST, BT 90 min/session 2 sessions/wk, 48 wks	MMSE WMS-LM I LVFT	A A A
Suzuki et al. (37)	RCT	74.8 ± 7.4	ET, ST, BT 90 min/session 2 sessions/wk, 24 wks	MMSE WMS-LM I	A A
Shubert et al. (45)	Non-RCT	79.6 ± 6.8	ET, ST, BT, FT 60 min/session 2 sessions/wk, 48 wks	TMT-A SDMT	A A
Taguchi et al. (26)	RCT	NM Age range: 74–96	ET, ST, BT, FT 90 min/session 1 session/week, 48 wks	MMSE	B
Vaughan et al. (34)	RCT	NM Age range: 65–75	ET, ST, BT, FT, CT 60 min/session 2 sessions/wk, 16 wks	TMT-A TMT-B COAST-Word test COAST-Interference COAST-Total Time COWAT-FAS-Total	A A A A A A

SD, standard deviation; RCT, randomised controlled study; A, positive result (beneficial impact of MCT); B, neutral result (no effect of MCT); ET, endurance training; ST, strength training; BT, balance training; FT, flexibility training; CT, coordination training; WMS-LM, logical memory scores; MMSE, mini mental state examination; LVFT, letter verbal fluency test; TMT, Trails making test; SDMT, Symbol Digit Modality Test; COAST, California Older Adult Stroop test; COWAT, Controlled Oral Word Association Test; NM, not mentioned; wk, week.

Table 5 Summary of studies that analyse the effects of MCT on quality of life

Reference	Study design	Mean age ± SD (years)	Protocol type	Outcomes	Results
Rubenstein et al. (25)	RCT	76.4 ± 4.9	ET, ST, BT 90 min/session 3 sessions/wk, 12 wks	SF-36	A
Worm et al. (27)	RCT	81.2 ± 4.2	ET, ST, BT, FT 60 min/session 2 sessions/wk, 12 wks	SF-36	A
Binder et al. (21)	RCT	83.0 ± 4.0	ET, ST, BT, FT, CT 3 sessions/wk, 36 wks	SF-36	A
King et al. (32)	RCT	77.0 ± 4.5	ET, ST, BT, FT 75 min/session 2 sessions/wk, 48 wks	SF-36	B
Barnett et al. (35)	RCT	74.9 ± 5.4	ET, ST, BT 24 wks	SF-36	B

SD, standard deviation; RCT, randomised controlled study; A, positive result (beneficial impact of MCT); B, neutral result (no effect of MCT); ET, endurance training; ST, strength training; BT, balance training; FT, flexibility training; CT, coordination training; SF, Short Form Health Survey; wk, week.

(20,21,26,27,30) and one non-RCT (41); and in five RCTs (19,22,24,25,33) and six non-RCTs (38,39,42–45) when posttraining values were compared with baseline ones (muscle strength gain ranging from 1.4% to 95.0%).

Functional fitness

Functional fitness was investigated in 23 studies (19–21,23–35,39–45) and this through four different outcomes (balance, gait ability, flexibility and exercise capacity).

Balance: Fourteen studies considered balance (Table 3) and eight different assessment tests were considered [i.e. one leg stance test (21,25,26,34,35,39,45); tandem test (32,33,45); Berg balance scale (21,27); postural sway test (29,35); functional reach test (41,42); balance score test (31); coordinated stability score (35) and stride length test (26)]. Compared with control groups, a significant improvement was reported by seven studies (21,26,27,31,32,34,41); and in the training group compared with baseline values in five studies (25,33,35,39,42). According to the study, the improvement was estimated between 5.3% and 88.9%.

Gait ability: Fourteen studies analysed gait ability (Table 3). The test the most frequently considered was the timed get-up and go test which was used in six studies (30,31,33,34,42,45). Gait abilities were also assessed by using the eight foot up and go test (19,20,24,43,44), the walking speed test (26,27,39), the gait score test (31), the 10-m walking test (27) and the 8-m gait test (32). Significant improvement in gait performance was reported by seven RCTs (19,20,26,30,31,33,34) and four non-RCTs (39,42–44), with a gain in walk ability ranging from 7.2% to 40.0%.

Flexibility: Fourteen studies reported flexibility (Table 3). The back scratch test was the measure most commonly used for the assessment and was considered in six studies (19,20,24,42–44). The sit-and-reach test was used in five studies (19,24,26,42,44). Compared with control group, a significant improvement was reported by three RCTs (19,24,26), and two non-RCTs (43,44) in the training group compared with baseline values with flexibility gain ranging from 12.0% to 89.0%.

Exercise capacity: Thirteen studies reported results on exercise capacity and they all considered the 6-min walk test (6MWT) as the outcome measurement (Table 3). Nine were RCT (19,20,23–26,29,32,34) and 4 non-RCT (40–43). A significant improvement was measured in all studies (performance gain ranging from 1.0% to 41.8%).

Risk of falling

When this incidence of falls was considered, six RCTs analysed the impact of MCT (26,28–30,33,35) (Table 3). Four studies reported benefits (26,28,29,35). Two studies found a significant reduction in the global risk of falls (22% and 40%, respectively) (29,35). One RCT showed significant 24.4 and 6% reduction of the risk of falling and the risk of fall-related injuries, respectively (28).

Effects of MCT on cognitive performance

Specific impacts of MCT on cognitive performance were measured in four RCTs (26,34,36,37) and 1 non-RCT (45) (Table 4) using either tests assessing the general cognitive functioning or specifically targeting one or more specific cognitive functions. While the mini mental state examination was usually considered to test the global cognitive functioning (26,36,37); the symbol digit modalities test was used in one study (45) and one study has combined the California older adult stroop Test and the Controlled Oral Word Association Test (34). Visual attention and task switching were particularly investigated by using the trail making test (34,45) and the logical memory test (36,37), respectively. The result of the MCT was a significant improvement in three RCTs (34,36,37) and one non-RCT (45) with a performance gain for cognitive functioning ranging from 1.1% to 30.6% according to the studies and the cognitive function investigated.

Effects of MCT on QoL

QoL was the outcome for 5 RTCs (21,25,27,32,35) (Table 5) in which the short form health survey score (SF-36) was considered. With this useful and validated indicator for change in QoL over time and treatment, the QoL was improved in three studies (QoL gain ranging from 18.0% to 35.9%) (21,25,27).

Discussion

To the best of our knowledge, this is the first systematic review specifically dedicated to the effects of MCT in senior population (i.e. adults aged 65 years or over). This population is of high interest because it cumulates at the same time the most expending rate within the general population and the highest risk of developing chronic comorbid health-conditions across all ages (46). By identifying the available literature (19 RCTs and 8 non-RCTs) this review provides a good level of evidence regarding the effect of MCT exercise in seniors exclusively. Thus, when guidelines stress the importance of MCT exercise in older adults (13,47,48), this systematic review demonstrates that MCT positively impacts cardiorespiratory fitness, serum lipids profile and body composition, functional abilities (i.e. muscle strength, balance and gait abilities, flexibility and exercise capacity), but also contributes to reduce the risk of falling, improve cognitive functioning and more modestly the QoL of seniors. This review is, however, affected by the heterogeneity in methods, exercise interventions and outcome measurements between studies. This is particularly true for the cognition where general and specific functioning were considered simultaneously, and finally the body composition where different technologies (bioelectrical impedance analysis, DEXA) were considered to measure the same body weight component (fat mass; fat-free-mass). It is probably why the benefit on body composition is less consistent across the studies identified; the same reasons which can contribute to the inconsistency of the relationship between the body composition and cardiovascular health (49).

Many reviews concerning the benefit of training programme in older adults have already been written but nearly all focused on unimodal training programmes. One report has reviewed the health benefits of MCT specifically for older adults (10). The authors have concluded to a positive effect on falls prevention, and small and limited effect on physical, functional and QoL outcomes. While the limited data available (i.e. 15 studies) had probably contributed to that conclusion, Baker et al. had also included home-based training programmes conducted without supervision. Those types of programme are well recognised now as training programmes that are less effective than supervised ones (50). The role of supervisor and feedback are very important and this especially for older adults. This contributes to explain why our findings are not exactly in the same line. Our conclusions roughly confirmed Baker et al.' conclusions (10), with, however, a greater effect on the risk of falling (four positive studies out of the six studies included). Similarly, the smaller effect on the QoL was also highlighted.

Future research should include robustly designed RCTs that more particularly involve MCT exercises at individually prescribed intensities (e.g. at doses found to be effective in single modality studies) because as well as the frequency of training, the intervention duration, and the intensity (i.e. maximum heart rate, heart reserve, VO_{2peak}) were widely heterogeneous between the study included (as described in Tables 1–5) or, for the last, not reported in the majority of studies (10).

In the line with our results, MCT exercises appear to be effective for improving general health of seniors and frail older adults (19,29,35,39). Thus, at any age, seniors should be encouraged to engage in well-designed and well-rounded MCT programmes which consider at once endurance/aerobic, strength/resistance, balance/stability and flexibility exercises. Such programmes are indeed expected to reduce the impact of sedentary lifestyle on general health and QoL. From that it might be also a favourable way to contribute to the limitation of the health-associated costs and polypharmacy that result from this way of life (51). However, if sedentary seniors should be encouraged to start training exercises with low-intensity physical activities, training programmes must also be tailored to the individuals' specific needs, interests and expectation, and this, to maximise participation and favour long-term adherence (13,47). The last can be, of course, also favoured by making physical activity a part of one's lifestyle (52). With this in mind, group-based exercises programmes supervised by professional trainers are known to be safe, effective, and also are an excellent way to initiate physical training generally, and in ageing and aged adults as well (53). This type of programme has also some collateral advantages as enhancement of long-term adherence among participants. It also favours social interactions and mutual commitment between trainees. Receive from professional trainers some instructions in proper techniques associated with a qualified supervision are also important features (47). Group-based exercises programmes supervised by professional trainers are also more effective than home-based training programmes among older patients (21,28).

According to the American College of Sports Medicine and the American Heart Association recommendations (13,47,48), aged adults should be encouraged to perform 30 min of moderate-intensity aerobic physical activity (40–60% of maximum heart pulse rate) during most days of the week (e.g. 2.5 h/week) or vigorous-intensity aerobic activity for at least 20 min 3 days/week. Muscle-strengthening activities on 2 or more days a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders and arms) are also recommended as well as flexibility activities on at least 2 days a week for at least 10 min a day, and, especially for community dwellers, 1–7 days/week exercises that contribute to maintain or improve balance abilities (13,47,48). These recommendations specifically focus on four major activities that are affected during the ageing process and contribute to the age-related functional decline. Hence, they are the key components of physical activity programmes designed for seniors: endurance/aerobic, strength/resistance, balance/stability and flexibility activities.

Regular resistance training limits muscle atrophy (54), whereas aerobic exercises restore and improve cardiovascular fitness and better control high blood pressure (55), and finally minimise the risk of coronary diseases (56). Balance exercises not only significantly reduce the risk of falling, as already mentioned, but also improve dynamic balance and to better manage the fear of falling (57). Flexibility-related activity facilitates greater range of motion around the joints and increases the length of the muscle beyond that customarily used in normal activity (47). Participants can be shown that flexibility activities fit conveniently into ordinary daily routines, for instance while sitting at a computer or watching other screens, or travelling in an airplane; stretching should include appropriate static and dynamic techniques. All combined together, it is clear that these training components contribute to a better physical and functional health (58).

Despite accurate guidelines, research evaluating tool-kits and programmes such as the 'First Step to Active Health' supporting the use of MCT in this population (44), or the effects of group-based and MCT interventions in community-dwelling senior are very limited (10,59–61). At least in part, this statement results from common barriers to engagement of seniors in training programmes (62–64). Low socioeconomic and/or poor health status, the necessary time commitment required, an unsupportive physical environments, and the preconceived negative notions regarding the concept of exercise are some of the factors commonly claimed (62–64). In response, the heterogeneity of the older people in terms of cardiovascular fitness, muscle strength, ability to perform basic and instrumental activities of daily life, health comorbid conditions and psychosocial needs and expectation must be taken into account to design appropriate programmes. In addition, by increasing the benefits of participation, economic theory suggests that the use of incentives could increase participation rates in structured programmes. Incentives have been shown to be effective in positively shaping various health behaviours and health outcomes although there is limited data on its suitability and efficacy among older adults (65). Moreover, even if effective, incentives come with a cost. One way to offset the cost is to include an enrolment fee. It is possible that the fee may deter some potential participants, but the net effect of incentives and an enrolment fee in affecting uptake by older adults in structured programmes remains an empirical question. Some recent data suggest the potential for even modest incentives to increase programme uptake among inactive older adults (66). Although cash was the most preferred option, supermarket vouchers, which could potentially be purchased at a discount, could be a close alternative. Enrolment fee is also a viable option to offset the costs of incentives as it has only minimal impact on participation (66).

Physical activity is complex, multifactorial and multi-dimensional health behaviour. The role of general practitioners (GPs) in counselling a patient to adopt behaviour change or maintain such behaviour is at least equally complex. It involves forming a specific partnership with the patient; defining the target behaviour (e.g. increasing physical activity and decreasing sedentary behaviour); exploring and addressing the unique combination of personal, socio-cultural, environmental, policy factors underlying the patient's behaviour; and finally identifying the most suitable (patient-centred) approach(es) to mobilise and help the patient sustain the behaviour. Long-term adherence to physical activity is essential for the health benefits to be realised. Interestingly, while it is generally acknowledged that GPs have a significant role in health promotion and prescription, physiotherapists' perceptions of this role varies. Patient education has become an essential part of health care, enabling him/her to participate in the decision-making (67). Critically, it is also the responsibility of GPs physiotherapists to educate their patients. Given their unique patient contact and broad patient access, they are advantageously positioned to do so across the lifespan and among all settings. Thus, by combining effective education, which should be tailored in content and delivery to the patient's individual learning needs, and the principles of behavioural change, GPs have the potential to achieve: (i) increased knowledge and awareness of risks of physical inactivity and the benefits of physical activity; (ii) increased knowledge and awareness of physical activity, what it can entail and how it can be achieved, including use of the services available, hence increasing self-efficacy and potentiating adherence to a new lifestyle; (iii) a change in attitudes and motivations for engaging in physical activity and (iv) a change in beliefs and perceptions about physical activity, sedentary behaviour and social norms. Moreover, in case of the lack of supervised training programme closed to senior's home, GPs should be able not only to encourage senior to be more active and this through simple, safe and attractive physical activities using easily administrable and cost-effective equipment's (i.e. cycling, walking, swimming), but also to recommend the amounts and types of physical activity that match with senior's abilities and health condition (42). In addition, one of the easiest way to adopt a more active or less sedentary behaviour is through increasing the amount of low-intensity physical activity performing throughout the day (e.g. use active transportation or public transit, take a family walk after dinner, take the dog for a walk, take the stairs as often as possible, park the car as far from the front door as possible, gardening and spend less time watching screens) (68).

In recent years in France, different initiatives to promote healthy ageing have been implemented. As an example, the 2007–2009 'Ageing Well' project aimed to improve the life of older persons by promoting regular physical activity (69) and has succeeded to convince the national health insurance fund (CPAM – *Caisse Primaire d'Assurance Maladie*) to support one endurance training programme specifically designed for seniors by the Geriatric department of the University Hospitals of Strasbourg (70). This programme was an 9-week 18-session intermittent work exercise programme (IWEP) performed on an upright electronically braked cycle ergometer. It consisted of a 30-min cycling workout twice a week that alternates aerobic and anaerobic activities. Each session involved six 5-min bouts of exercise, each of the latter separated into 4-min cycling at the measured pretraining ventilation threshold (VT_1) workload, alternated with 1-min cycling at 90% of the pretraining maximal tolerated power sustained during all the IWEP. When analysed, the results showed a significant (13–25%) improvement in the cardio-respiratory endurance parameters among participants. All seniors were fully convinced of the beneficial effect of such programme for their health and asked, after 18 sessions, to be authorised to continue to participate (70). The cost paid by the CPAM was 972€ which corresponded to two cycle incremental exercise tests (pre- and post-IWEP), one pre-IWEP echocardiography, 18 sessions on bicycle ergometer, and two outpatient consultations (pre- and post-IWEP). Resulting from these benefits and in accordance with the recommendations (8,9,47,71), our team has designed a new training programme with two other modalities consisting of strength/resistance and balance/stability exercises which are combined with the IWEP.

Whilst the present review was performed using eight electronic databases for the literature search and a wide range of disciplines has been scrutinised, it is limited in that it did not include unpublished data (including thesis dissertations) and the literature not edited in English. Additionally, these results are only generalisable to seniors similar to those recruited for the 27 studies analysed. In addition, clinical population such as patients with specific comorbidities or in rehabilitation programme for heart, respiratory or stroke were not included in the selected literature. Age was one of our inclusion/exclusion criteria, meaning that the results measured on all the outcomes investigated are robust. But, for sure, in clinical trials 'aged 65 years or over' is more frequently considered as a non-inclusion criterion for participants rather than an inclusion one. This probably means the exclusion from this review of RCTs and non-RCT only considering subgroups of aged adults rather than those where seniors represented the whole of the study population. But, for regarding the challenge to providing for older adults the best possible and valuable cares, it was just essential for us to only target this very specific and particular population.

Conclusion

This systematic review provides clinically relevant findings. With a good level of evidence, MCT demonstrates to induce beneficial effects on senior's cardio-respiratory fitness, metabolic outcomes, functional status, cognitive performance and QoL. Thus, MCT programmes seem to be particularly appropriate for sedentary seniors with respect to its ability to improve cardiorespiratory fitness. Furthermore, it can help to control metabolic outcomes such as serum lipid profile and, to some extent, towards a more balanced body composition. It seems to be an effective treatment for reducing the risk of falling and a beneficial way to increase muscle strength and functional fitness. Finally, MCT also contributes to improve global and specific cognitive functions, and has a significant impact on QoL. Based on those findings, it is really important to encourage seniors to engage in MCT to reinforce the current public health policy efforts.

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Author contributions

All the above listed authors meet the common criteria for authorship and approved publication of this manuscript. Walid Bouaziz, Elise Schmitt and Thomas Vogel have designed the study and collected the data. Walid Bouaziz, Bernard Geny and Georges Kaltenbach conducted the systematic review and interpreted the data. Walid Bouaziz, Pierre Olivier Lang, Elise Schmitt and Thomas Vogel have written and revised the manuscript.

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