Training in the functional movement circle to promote strength and mobility-related activities in older adults: a randomized controlled trial

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Abstract Movements of everyday life (e.g., climbing stairs, rising from a chair, walking) are essential for older adults to stay functional and independent. Due to the aging process, muscle mass decreases and balance abilities are reduced. One major criticism of former interventions is that implemented resistance and balance exercises were not associated with movements needed in older adults' everyday life. The Functional Movement Circle for older adults (FuMoC) includes the combination of three aspects: resistance, balance, and movements of everyday life. The aim of this study was to compare the effects of training in the FuMoC with those of other training programs. A randomized controlled trial (RCT) with three intervention groups (IG1: FuMoC; IG2: resistance and balance training; IG3: coordination training) with a training period of 6 months and one inactive control group (CG) was conducted. At baseline (T1), after three (T2) and six (T3) months, parameters of strength (isometric strength measurement and One-Repetition Maximum test in leg and chest press) and mobility-related activities (gait analysis, Multisurface Obstacle Test for Older Adults (MSOT), Chair Rise Test (CRT), Timed Up & Go Test (TUG), Maximum Step Length Test (MSLT)) were assessed as

primary outcomes. Data of 78 (43 males, 35 females) older adults were analyzed (mean age: 68.4 years). Significant ($p < 0.05$) interactions between time and group were observed in most of the primary outcomes. IG1 showed the highest improvement rates in MSOT (+16 %), CRT (+28 %), TUG (+14 %), and MSLT (+15 %); demonstrating advantages of training in the FuMoC compared to other training programs.

Keywords Intervention · Training program · Resistance training · Balance training · Movements of everyday life

Background

With increasing age, impairments in the sensory, motor, and central processing system occur in addition to biomechanical changes (Duclos et al. 2013). These processes lead to a decrease of balance, strength and power, neuronal, muscular, and bone-related degeneration (Al-Aama 2011; American Geriatrics Society 2011; Barrett-Connor et al. 2009; Fletcher et al. 2009; Granacher et al. 2013; Macaluso and de Vito 2004; Malafarina et al. 2012; Pizzigalli et al. 2011; Pluijm et al. 2006; Rogers et al. 2003; Rubenstein 2006). Despite the aging process, older adults want to stay independent right up to high age. Through improvements in muscle strength, muscle power, and balance, older adults could maintain a spectrum of movements of everyday life, e.g., rising from a chair, climbing stairs, and walking (Brill 2004; Henwood and Taaffe 2006; Schot et al. 2003). As a consequence of effective training programs, older adults could avoid, retard, and reduce decreases in physical performance (Brill 2004). The major goal of functional training is the enhancement and development of muscles to achieve a more effective, more secure, and less exhausting

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execution of movements in everyday life. To maximize benefits, exercises in training programs should simulate movements of everyday life (Taylor and Johnson 2008). In their systematic review, Granacher et al. (2013) intended to evaluate new intervention programs that were specifically designed to work against age-related impairments. Studies considered in this review showed positive effects of movements of everyday life in combination with balance exercises (Alfieri et al. 2010; Egerton et al. 2009; Mayer et al. 2011). However, studies that implemented traditional resistance training without any additional exercises also displayed comparable positive effects (Aagaard et al. 2010; Barry and Carson 2004; Bottaro et al. 2007; Manini et al. 2007). So it remains still unclear which training program is the most effective one for movements in everyday life.

Indeed, previous studies have included a combination of all three aspects (resistance, balance, movements of everyday life) in their programs, but often in separate sessions. All integrated exercises must be defined in aspects of movement velocity, range of motion and trained muscle groups to attain-specific effects. For example, existing resistance training methods (e.g., hypertrophy, inter-muscular coordination, maximum strength) trigger different acute physiologic and metabolic effects (Garcia-Manso et al. 2012; Gentil et al. 2006). At the point when the physiological systems have adapted to a given stimulus, higher challenges (difficulty, load intensity, volume) are required to achieve further improvements. Particularly, load intensity (% of the One-Repetition Maximum [1RM]) and volume (sets and repetitions) are crucial concerning the responses of resistance training, because intensity and duration of muscle tension are responsible for neuronal and morphological adaptations (Buitrago et al. 2013; Crewther et al. 2006, 2008; Froehlich et al. 2002; González-Badillo et al. 2011; McBride et al. 2009). Several former studies did not provide a detailed description and systematically planned implementation of training control parameters as load intensity or difficulty of the exercises, which is one major criticism (Granacher et al. 2013).

Within the Functional Movement Circle for older adults (FuMoC), a combination of all three types of exercises in each training session, and the detailed planning and implementation of systematic progression of both load intensity and difficulty are highly innovative aspects. It was hypothesized that training in the FuMoC could evoke similar improvements in strength parameters compared to an identical traditional resistance and balance training without movements of everyday life. However, training in the FuMoC is expected to cause higher improvements in movements of everyday life both in comparison to resistance and balance training without movements of everyday life and compared to traditional coordination training.

Methods

Study design

The study was a randomized controlled trial (RCT) with three intervention groups (IG1: FuMoC; IG2: resistance and balance training; IG3: coordination training) and one control group (CG) in a parallel group design. All enrolled participants were informed prior to the first measurement appointment to exclusively inform colleague B (a colleague of the main researcher = first author) about their group allocation. First of all, the main researcher prepared a box with corresponding random numbers (IG1 and IG3: $n = 20$; IG2 and CG: $n = 19$) of notes with information about the training (IG1-3) or instructions for behavior (CG). After the baseline (T1) measurements, participants were instructed to draw one lot out of the box and follow the instructions presented on their lot. Participants had to inform only colleague B about their group allocation. Colleague B built a list with participant-IDs and group allocation (A, B, C, D) with no information about IG or CG. After the analysis of all data, the main researcher received the list containing the group assignment information for the description and interpretation of data. Afterward, colleague B asked every involved person in the blinding process whether participants had carefully followed the instructions guaranteeing blinding. No deviation from the planned and described process was present. The ethics committee at the German Sport University Cologne granted ethical approval. The study design took into account the principles set out in the Helsinki declaration (2008). All participants completed informed consent forms. Participants were informed that all the data collected would be processed anonymously. No changes to methods were made after trial commencement. The study was conducted in the city of Cologne, Germany.

Participants

The target population of the study was community-dwelling older adults aged 60 years and older. Participants were recruited by advertisements placed on web pages, in local newspapers, posters, and flyers in Cologne and the surrounding area. After the development of the FuMoC, the aim was to implement the planned exercises with an overall healthy sample of older adults without any limitations. It was expected that this sample could execute all exercises as planned. Initially, 187 older persons were interested in participating in the study. There was no a priori sample size calculation. Detailed eligibility was checked in a second step via a health questionnaire. Furthermore, the physician of potential participants had to provide them with a medical clearance certificate confirming that none of the

mentioned exclusion criteria were present. Based on the following exclusion criteria, 89 persons were excluded: thrombophlebitis ($n = 3$), infections ($n = 5$), renal ($n = 2$), or hepatic ($n = 4$) problems, disc prolapse during the last 6 months ($n = 18$), unstable diabetes ($n = 12$), neurological ($n = 6$), and neuromuscular ($n = 2$) diseases or arterial hypertension ($n = 19$), diagnosed gait disorders ($n = 3$), artificial joints ($n = 8$), and need of walking aids ($n = 5$). Exclusion criteria were recorded in the order presented before so that the first compliance with a criterion was decisive for counting. Another reason for exclusion was the lack of ability to sit or stand without aid ($n = 2$). After being informed of the detailed time frame and the specific content of the study, twenty persons declined to participate ($n = 16$ time problems; $n = 4$ not interested in the specific interventions). Due to the exclusion criteria and the eligibility process described above, 78

older adults were included in the study. The flowchart of the study is presented in Fig. 1.

Intervention

After T1, the intervention groups commenced their training twice a week, with a minimum of 2 days rest between consecutive training sessions and duration of 60 min per session. All training groups were instructed by a team of six instructors (three master students of movement and sport gerontology and three bachelor students of sports, health, and prevention). A schedule with a systematically planned rotational system warranted equivalent amounts for all instructors in each group. All instructors were trained and supervised by the main researcher prior to the beginning of the study and during the intervention phase.

Fig. 1 Flowchart of the study

Intervention group 1 (IG1) and intervention group 2 (IG2)

The warm-up procedure was identical in IG1 and IG2. To prepare both upper and lower limbs, participants had two options: (a) a 10 min session on a cross ergometer or as an alternative (b) a 5 min session on a bike followed by 5 min on a hand crank ergometer.

The exercise regimen contained six progressively increasing resistance exercises and two balance exercises with advancing difficulty levels. Participants trained in pairs. In our study, resistance training was used as genus for different training methods: training to increase muscle mass (hypertrophy training) and training to increase muscle power (power training), through the generation of high maximum strength as fast as possible.

For the resistance training, training machines (leg press, chest press, cable column: standing abduction and adduction [ERGO-FIT, Pirmasens, Germany]) and two exercises on a gymnastic mat (back extension and crunches) were applied. The load standards (intensity, number of sets and repetitions, duration of rest, conducted method) and configurations for the resistance exercises (volume, work, time under tension per exercise, forms, and time for contraction forms) within the first 12 weeks of training (phase1 = p1) are displayed in Tables 1 and 2. Load intensity was gradually increased, adapted by subjectively perceived exertion (OMNI-RES scale; Robertson et al. 2003). Each training phase of 3 months was divided into 8 weeks of hypertrophy training followed by 4 weeks of power training. In the second 3 months (phase2 = p2), only load intensity was increased up to 70–85 % of 1RM (hypertrophy phase) and 60–70 % of 1RM (power phase), respectively. All additional variables were maintained at the same level.

The two balance exercises were conducted on an AI-REX[®] pad and on a 3D whipping spin top. These exercises,

with their corresponding intensities, durations, and levels of difficulty, were also identical in IG1 and IG2. The levels and accompanying changes of the exercises are presented in Table 3.

Intervention group 1 (IG1)

IG1 carried out training in the FuMoC with the presented resistance and balance exercises accompanied by the specific track (width: 80 cm, length: 24 m [4 × 6 m]) with movements of everyday life (stair climbing, overcoming road curbs) and different surfaces (carpet, stones, artificial grass). This track was installed in a circle around the other stations. Round and flat pebble stones, wooden plates and road curbs (simulated by 10 cm- and 15 cm-high wooden boxes); eight Terrasensa[®] plates (Ludwig Artzt GmbH, Dornburg, Germany), a carpet (simulating grass), four mini hurdles (2 × 20 cm; 2 × 30 cm high; Eveque Sportshall Hurdles, Walsall, United Kingdom), and three stairs up and down were used within the track. While one partner was situated at one station the other partner had to walk along the track as an active rest. Once completed, the participants swapped places.

Intervention group 2 (IG2)

Participants of IG2 received the same training program provided in IG1 with the exception of not completing the specific track. In contrast to IG1, IG2 had an inactive rest (standing beside the station).

Intervention group 3 (IG3)

Training of IG3 was based on the contents of traditional courses in a sports club. A 10 min warm-up was followed

Table 1 Load standards for resistance exercises in intervention group 1 (IG1) and intervention group 2 (IG2) for the first 12 weeks of training (phase1 = p1)

T1 = measurement session 1 (baseline); T2 = measurement session 2 (3 months after baseline)
min minute, 1RM one-repetition maximum, OMNI-RES OMNI perceived exertion scale for resistance exercise

Week	Method	Sets	Repetitions	Rest [min]	% of 1RM	OMNI-RES
T1 assessment						
1	Hypertrophy	2	10	1	60	6–7
2			12		60	6–7
3			10		65	6–7
4			12		65	6–7
5			10		70	6–7
6			12		70	6–7
7			10		75	7
8			12		75	7
9	Power	2	6	2	40	4–5
10			8		40	4–5
11			6		50	5
12			8		50	5
T2 assessment						

Table 2 Load configurations for resistance exercises in intervention group 1 (IG1) and intervention group 2 (IG2) for the first 12 weeks of training (phase1 = p1)

Load parameter	Hypertrophy	Power
Intensity (% of 1RM)	60–75	40–50
Repetitions per set	10–12	6–8
Number of sets	2	2
Volume (sets $\times$ repetitions)	20–24	12–16
Work [(load intensity $\times$ volume)/100]	12–18	4.8–8
Rest between sets [s]	60	120
Rest between repetitions [s]	0	0
Number of sessions per week	2	2
Duration of the training period [weeks] (total)	8	4
Arrangement of the contraction forms: duration of time under tension per repetition [s]		
Iso sp	0.5	Minimal (a)
Conc	2	Explosive (b)
Iso ep	0.5	Minimal (a)
Exc	3	2
Total	6	2 + a + b
Time under tension per exercise task [s]		
Iso	20–24	Minimal (a)
Conc	40–48	Explosive (b)
Exc	60–72	24–32
Total	120–144	(24 + a + b)–(32 + a + b)
Work _{tut} [(load intensity $\times$ volume)/100] $\times$ time under tension] [s]		
Iso	240–432	(4.8 + a)–(8 + a)
Conc	480–864	(4.8 + b)–(8 + b)
Exc	720–1,296	115.2–256
Total	1,440–2,592	(115.2 + a + b)–(256 + a + b)
Muscle fatigue	rm	
Regeneration time between training sessions	2–4 days	

s seconds, *1RM* one-repetition maximum, *tut* time under tension; muscle contractions: *iso* isometric, *conc* concentric, *exc* excentric, *sp* start position, *ep* end position, *rm* repetition maximum, *a* minimal time, *b* time for explosive contraction

by the main part of the training program, comprising different exercises in conjunction with tools and small equipment to strengthen muscles (elastic bands, dumbbells, ankle weights) and improve coordination (obstacles, gymnastic bar, balance boards, gymnastic mats, balls). The main differences with IG1 and IG2 were lighter weights (high weights are less available in sports clubs), more variations in applied means and a less stringent systematization in training control. At the end of each session a 5 to 10 min cool down was performed.

Control group (CG)

Participants of CG were encouraged to live their regular life and maintain their usual social and leisure time activities during the study period. They were offered

participation in the FuMoC training program subsequent to the study.

Measurements

All participants were measured by a team of two master students of movement and sport gerontology (different ones than the exercise instructors). They were not informed about group allocation of the tested participants, who were instructed prior the measurements to not inform the test conductors about the training or their group allocation. The two master students were trained by the main researcher prior to the beginning of the study and supervised during the measurements. Each measurement session (T1–T3) started with a 10 min warm up on a cycling ergometer for lower limbs with 1.0 watt per kg body weight and 10 min

Table 3 Progression of difficulty levels within the balance stations

Equipment	Phase	Week	Exercise
AIREX [®] pad	1	1	2 × 45 s, Bipedal stance
		3	2 × 30 s/leg, Single leg stance
		7	2 × 30 s/leg, Single leg stance, free leg forward and backward swinging
		11	2 × 45 s/leg, Single leg stance, free leg forward and backward swinging
AIREX [®] pad + teeterboard (forward/backward)	2	1	2 × 30 s, Bipedal stance
		5	2 × 45 s, Bipedal stance
		9	2 × 60 s, Bipedal squats
3D Whipping spin top	1	1	2 × 45 s, Bipedal stance
		3	2 × 30 s/leg, Single leg stance
		7	2 × 30 s/leg, Single leg stance, free leg sideward swinging
		11	2 × 45 s/leg, Single leg stance, free leg sideward swinging
	2	1	2 × 30 s, Bipedal squats
		5	2 × 45 s, Bipedal squats
		9	2 × 60 s, Bipedal squats

s seconds

on a hand crank ergometer for upper limbs with 0.5 watt per kg body weight. All measurement procedures were identical at T1–T3. To operationalize movements of everyday life, the following performance-based tests of mobility-related activities were implemented (see Table 4): gait analysis on flat ground, the Multisurface Obstacle Test for Older Adults (MSOT) with habitual and maximal speed, the Chair Rise Test (CRT), The Timed Up & Go Test with the normal and two modified versions, and the Maximal Step Length Test (MSLT with both feet). To increase the difficulty in the TUG and provide further information about dual-task conditions within the TUG, modified versions with an additional cognitive and with an additional motor task were executed. Afterwards, the measurements of strength and secondary outcome measures were conducted.

Measurements of strength included the examination of isometric strength (N) in the leg and chest press (ERGO-FIT, Pirmasens, Germany) with a piezoelectric force transducer (leg: 5 kN; chest: 2 kN; sample rate 1,000 Hz, measurement error ± 0.5 %). Participants' strength of the lower limb muscles (leg press) was quantified in a seated position with a hip angle and an inner knee flexion angle of 90°. For measurements in the chest press, a sitting position with an angle of 60° between upper arm and trunk was set. The inner elbow angle was 120°. After a first submaximal familiarization trial, three additional trials followed. The first trial (maximal voluntary contraction = MVC) delivered the reference value for trials two and three. Participants started with a minimal muscular pretension and generated the maximal muscular strength as strong and as fast as possible against the fixed weight. In the second and third trials, participants started with a muscular pretension

of 5–15 % of MVC, which was displayed by online feedback of the developed strength. Such a muscular pretension could avoid false strength peaks in isometric strength measurements (Morat and Preuß 2014). In former studies measuring isometric strength, this method indicated high reliability with ICC > 0.84 (Ford-Smith et al. 2001; Stoll 2002; Viitasalo et al. 1980).

Isometric strength was used to estimate the weight for the 1RM test in kilogram (isometric strength in Newton divided by gravitation = 9.81 m/s²). For measuring dynamic strength, the One-Repetition Maximum (1RM) test was then executed according to the testing protocol of Earle (2006) in the leg press. For warm-up purposes, participants had to execute eight repetitions with 30 % (1 min rest), four repetitions with 50 % (2 min rest) and two repetitions with 80 % (3 min rest) of this estimated weight. After the warm-up, the measurement trials with maximum weight (in kilogram) that could be moved with the correct technique throughout the full range of motion were executed. To prevent fatigue, a maximum of five trials was conducted. Each trial was followed by three minutes of rest. After a successful trial, weight was increased by 10 %; an unsuccessful trial led to a weight decrease of 5 %. With this procedure, participants reached their maximum weight. Subsequently, the same procedure was repeated for the chest press. Levinger et al. (2009) reported an ICC > 0.90 for the 1RM test.

To examine physical activity, leisure time and social activities were recorded as secondary outcome with the German Physical Activity Questionnaire 50⁺ (Huy & Schneider 2008). Another purpose was to examine intervention effects on quality of life as a general parameter of well-being using the Short Form 36 Health Survey

Table 4 Performance-based tests of mobility-related activities with their characteristics [unit], description, number of trials, rest period between trials, variables for analysis, quality criteria and references

	Measurement	Characteristics [unit]	Execution	Number of trials	
1	Gait analysis on flat ground ("RehaWatch" by HASOMED, Magdeburg, Germany)	-Gait velocity [m/s] -Cadence [steps/min] -Stride length [m] -Duration of swing phase [%] -Duration of bipedal stance phase [%] -Mean maximum ground distance [m] Time [s]	Walk of ten meters with one meter for acceleration and one meter for deceleration	One familiarization trial, two trials with normal speed, two trials as fast as possible while considering safety	
2	MSOT MSOTnorm: habitual speed MSOTmax: maximal speed		Walk of ten meters on a gait track including different uneven surfaces and movements of everyday life	One familiarization trial, two trials with normal speed, two trials as fast as possible while considering safety	
3	Chair Rise Test (CRT)	Time [s]	Completion of five complete repetitions with arms crossed in front of the chest	One trial	
4	Timed Up & Go Test (TUG) (a) TUGnorm (b) TUGcog (c) TUGmot	Time [s]	(a) Get up from a chair, walk three meters straight on, turn around a cone, walk back and sit down (b) With an additional cognitive task (counting backwards from 97 in steps of three) (c) With an additional motor task (transporting a cup with water)	One trial of each condition (in cases of spilled water: additional (revision) trial)	
5	Maximal Step Length Test (MSLT) right foot left foot	Distance [cm] between front heel and back toe	Step forward as far as possible without losing balance and step backward in the starting position (no lift of the standing leg in the back)	Five trials with each foot	
	Measurement	Rest period between trials	Variables for analysis	Quality criteria	References
1	Gait analysis on flat ground ("RehaWatch" by HASOMED, Magdeburg, Germany)	30 s	Best trial of each condition	High reliability with ICC > .96	Peters et al. (2013)
2	MSOT MSOTnorm: habitual speed MSOTmax: maximal speed	30 s	Second trial of each condition	High reliability with ICC > .92	Morat et al. (2013)

Table 4 continued

Measurement	Rest period between trials	Variables for analysis	Quality criteria	References
3 Chair Rise Test (CRT)	–	One trial	High reliability with ICC > .94	Goldberg et al. (2012)
4 Timed Up & Go Test (TUG) (a) TUGnorm (b) TUGcog (c) TUGmot	30 s	One trial of each condition	High reliability with ICC > .98 for the normal version	Podsiadlo and Richardson (1991)
5 Maximal Step Length Test (MSLT) right foot left foot	30 s	Mean of five trials (separated by feet)	High reliability ICC > .90	Freiberger and Schoene (2010), Goldberg et al. (2010, 2012), Medell and Alexander (2000)

s seconds, min minutes, m meters, cm centimeters, CRT chair rise test, MSOT multisurface obstacle test for older adults, TUG timed up & go test, TUGnorm normal version, TUGcog with an additional cognitive task, TUGmot with an additional motor task, MSLT maximal step length test, ICC intraclass correlation coefficient

(Bullinger 1995) as well as fear of falling using the Falls Efficacy Scale – International (Dias et al. 2006). To expand this, falls (number of falls) were recorded with a fall diary provided by Freiberger and Schoene (2010). In accordance with the Prevention of Falls Network Europe (ProFaNE) a fall was defined as “an unexpected event in which the participants come to rest on the ground, floor, or lower level” (Lamb et al. 2005, p. 1619). Freiberger and Schoene (2010) distinguished events every day between “F” as an unintentional fall at ground level with injuries, “S” as slipping unintentionally at ground level without injuries, “T” as tripping that means stumbling with swaying body without falling at ground level and “N” as nothing noticeable happened. 3 months before T1 participants started to fill in a diary (every day) and kept doing this during the whole period of the study. The phases were defined as: in the last 3 months before T1 (phase0 = p0), during the first and second 12 weeks after T1 (T1–T2: phase1 = p1; T2–T3: phase2 = p2) and a 3 month (phase3 = p3) and 6 month (phase4 = p4) follow-up. Participants received fall diaries for every day in which they had to check one out of four possibilities that happened during the concerned day by stating the worst case of the four events. In every phase of the study, participants had to send in their daily completed fall diaries at the end of each month. Otherwise, they received a phone call reminder to avoid missing data. If a fall happened, participants were instructed to directly inform the main researcher. Afterwards, an additional fall protocol had to be completed and an additional personal phone call with the main researcher was realized. There were no changes to the trial outcomes after the trial commenced. For the consideration of feasibility, the exercise instructors recorded in a log book training attendance, realized load (weight) and perceived exertion with the OMNI perceived exertion scale for resistance exercise (OMNI-RES) (Robertson et al. 2003).

Statistical analysis

Data is presented as means (M) $\pm$ standard deviations (SD). Within this study, an intention-to-treat analysis with data of 78 cases was performed. Missing data of drop-outs (see flow chart Fig. 1) was analysed with the MCAR-Test (missing completely at random) by Little. Afterwards, a multiple imputation for monotone missing data with ten imputations (Jekauc et al. 2012) was performed with SPSS to maintain a complete dataset of all randomized 78 cases. With the Levene test (if necessary including Lilliefors correction), the normal distribution of the data was inspected statistically. A two-factor repeated-measures ANOVA, as a mixed design (general linear model) with main effect of factor one (time) and factor two (group) and interaction effects of factors one and two, was used. In the

case of no sphericity, the Greenhouse-Geisser correction was used. If the ANOVA displayed significant effects, the estimated marginal means (EMMEANS) with Bonferroni correction were used (post hoc) to identify the specific significant differences between individual groups or measurement sessions. Using the software GPower (v3.0.10) (Faul et al. 2007), effect size f and power were calculated a posteriori based on the variances explained by special effect and error variances. An $\alpha < 0.05$ was considered statistically significant.

Results

Participants

The data of the baseline characteristics (see Table 5) displayed no significant differences between the groups (except for the Timed Up & Go Test with an additional motor task, TUGmot), which is indicative of a successful randomization process.

Outcome measures

Changes in parameters of strength and performance-based tests of mobility-related activities with the statistical values of the tests are displayed in Table 6. With two exceptions (the normal version of the Timed Up & Go Test [TUGnorm] and all measured gait parameters), all primary outcomes showed significant ($p < 0.05$) interactions between time and group.

In some of the primary outcomes there was significant ($p < 0.05$) group influence at the different points of measurement. The post hoc analysis detected significant group differences in the Multisurface Obstacle Test with normal speed (MSOTnorm) at T3 between IG1 and all other groups (IG2: $p = 0.021$; IG3: $p = 0.014$; CG: $p < 0.001$) and in the MSOT with maximal speed (MSOTmax) between IG1 and CG ($p = 0.010$). In the Timed Up & Go Test with an additional cognitive task (TUGcog), there were significant group differences at T3 between IG1 and IG3 ($p = 0.016$), IG 1 and CG ($p = 0.003$). The same test with an additional motor task (TUGmot) showed significant mean differences at T2 between IG1 and CG ($p = 0.037$) and at T3 between IG1 and CG ($p = 0.049$). The Chair Rise Test (CRT) showed a significant group difference at T3 between IG1 and CG ($p = 0.005$).

Effect sizes f for the different tests showed large effects ($f > 0.40$) in several measurements. The normal version of the Timed Up & Go Test (TUGnorm; $f = 0.29$) indicated a medium effect size, the 1RM test in leg press and isometric strength in chest press showed a medium to large effect ($f = 0.39$) (Cohen 1988). The calculated power for most of

the tests displayed high values of power between 0.68 and 0.97 and medium power of 0.41 for TUGnorm (see Table 6).

In the secondary outcomes, results of the German Physical Activity Questionnaire 50⁺ ($p = 0.12$) and the Falls Efficacy Scale-International ($p = 0.67$) showed no significant interactions between time and group. The Short Form 36 Health Survey displayed a significant interaction between time and group ($p = 0.001$) with significant group differences at T2 between IG1 and IG3 ($p = 0.045$) and at T3 between IG1 and CG ($p = 0.002$).

Within the training sessions, no fall or injury occurred. However, regarding the data of falls, different participants had fallen during the study period. The range (and total number = tn) of falls varied within p0–p4 between 0 and 3 falls in IG1 ($tn:4$), 0–3 falls in IG2 ($tn:8$), 1–3 falls in IG3 ($tn:12$) and 2–4 falls in CG ($tn:12$). There was one recurrent faller in CG. Data showed a reduction of falls for IG1 and IG2 and small changes in IG3 and CG during the study period. All falls occurred outside of the study, for example whilst gardening, going for a walk at night or other activities. The participants who had fallen experienced no severe injuries (abrasions or contusions). Two participants (CG) consulted their family physician with no further consequences. The exercise regimens of all three intervention groups were implemented as planned. A high training attendance in all three training groups was recorded in both training phases (p1 and p2). The highest rates were obtained in IG1 (p1: 82.5 %; p2: 86.9 %), followed by IG3 (p1: 78.3 %; p2: 77.6 %) and IG2 (p1: 77.6 %; p2: 76.8 %). There was no significant difference between the groups regarding training attendance. There were no harms or unintended effects in any of the groups. After the end of the study, ten participants (two declined because of time problems; seven dropped out earlier) of CG took the chance to train in the FuMoC.

Discussion

The aim of this study was to compare the effects of training in the FuMoC with those of two other training programs and one inactive CG. Considering the groups and the levels of improvements in percentages, participants who trained in the FuMoC (IG1) showed the highest improvements in parameters of strength and performance-based tests of mobility-related activities. These findings confirm the hypothesis that training in the FuMoC can evoke similar improvements in strength compared to an identical traditional resistance and balance training without movements of everyday life. The second hypothesis was also confirmed. Training in the FuMoC caused the highest improvements in performance-based tests of mobility-

Table 5 Baseline characteristics for participants segmented by group

Characteristic	Protocol				<i>p</i> Value
	IG1 (<i>n</i> = 20) Mean ± standard deviation	IG2 (<i>n</i> = 19)	IG3 (<i>n</i> = 20)	CG (<i>n</i> = 19)	
Age [years]	69.4 ± 6.6	66.5 ± 4.9	69.0 ± 7.3	68.5 ± 5.9	0.51
Age range [years]	61–84	61–78	60–85	61–81	
Weight [kg]	72.8 ± 13.6	73.7 ± 14.6	79.8 ± 11.8	78.4 ± 12.1	0.26
Height [m]	1.70 ± 0.1	1.71 ± 0.1	1.72 ± 0.1	1.73 ± 0.1	0.72
Gender	9 m, 11f	10 m, 9f	13 m, 7f	11 m, 8f	
Strength					
Isometric strength in leg press [N]	906.25 ± 497.22	907.95 ± 388.86	948.42 ± 323.04	944.28 ± 391.03	0.98
1RM test in leg press [kg]	100.9 ± 32.6	108.3 ± 36.7	117.3 ± 27.4	107.6 ± 32.8	0.47
Isometric strength in chest press [N]	610.63 ± 297.58	627.63 ± 448.21	773.53 ± 368.36	754.70 ± 427.96	0.43
1RM test in chest press [kg]	34.1 ± 13.0	35.8 ± 14.2	41.5 ± 17.5	39.5 ± 15.8	0.41
Performance-based tests of mobility-related activities					
MSOT, habitual speed [s]	7.4 ± 1.4	6.8 ± 1.1	7.1 ± 1.3	7.3 ± 1.2	0.43
MSOT, maximal speed [s]	6.2 ± 1.4	5.4 ± 0.8	5.6 ± 1.3	5.9 ± 1.0	0.16
Chair Rise Test (CRT) [s]	12.0 ± 2.5	11.2 ± 1.6	11.9 ± 2.1	12.0 ± 2.3	0.63
Timed Up & Go Test (TUG) [s]					
TUGnorm	6.7 ± 1.6	6.1 ± 1.0	6.3 ± 1.0	6.5 ± 0.7	0.42
TUGcog	7.6 ± 2.1	6.9 ± 1.6	7.0 ± 1.4	7.4 ± 1.4	0.43
TUGmot	7.1 ± 1.7	6.0 ± 0.6	6.7 ± 1.0	6.9 ± 1.0	0.02*
Maximal Step Length Test (MSLT) [cm]					
Right foot	65.0 ± 17.2	74.5 ± 10.7	73.6 ± 17.8	69.7 ± 11.4	0.17
Left foot	65.1 ± 16.9	76.3 ± 11.4	73.1 ± 18.8	70.9 ± 10.7	0.13
Background variables					
German PAQ 50 ⁺ [MET]	16,598 ± 11,546	13,689 ± 6,802	14,724 ± 10,023	18,120 ± 17,560	0.68
FES-I [score]	17.3 ± 1.8	17.6 ± 2.0	17.3 ± 1.4	18.5 ± 2.5	0.15
SF-36 [score]	127.6 ± 12.3	125.5 ± 11.0	122.1 ± 14.3	120.4 ± 18.2	0.39

n number of participants, *kg* kilogram, *N* newton, *s* seconds, *m* meters, *IG* intervention group, *CG* control group, *m* male, *f* female, *1RM* one-repetition maximum, *CRT* chair rise test, *MSOT* multisurface obstacle test for older adults, *TUG* timed up & go test, *TUGnorm* normal version, *TUGcog* with an additional cognitive task, *TUGmot* with an additional motor task, *MSLT* maximal step length test, *German PAQ 50⁺* german physical activity questionnaire 50⁺, *FES-I* falls efficacy scale-international, *SF-36* short form 36 health survey, *MET* metabolic equivalent of task

* Significant difference at baseline between IG1 and IG2 (*p* = 0.02)

related activities. The traditional coordination training (IG3) in this study achieved small or no effects and maintaining habitual activities (CG) revealed no or negative effects on the measured variables.

The main focus was on strength parameters and performance-based tests of mobility-related activities. Especially in the Multisurface Obstacle Test for Older Adults the results of this study revealed very fast times between 5.4 and 7.4 s at baseline measurement. Compared to the study by Morat et al. (2013), the participants here were on average up to 2.7 s faster in completing the test; the hazard of ceiling effects at T1 is also reasonable. Considering this, improvements of 16 and 17 % in the MSOT in IG1 in the tested (fit) sample could yet be evaluated more positive. In the other measurements mainly large effect sizes occurred

and the power of many conducted tests was high. Despite imputation of missing data, the overall sample size should be larger to draw generalized conclusions. However, the results of the a posteriori calculated effect sizes within this study can be used to calculate the required sample size for a further study. The high drop-out rate of 26 persons throughout the overall study period was not expected, but the reasons for drop-outs could not be ascribed to the intervention. One problem was the young minimum inclusion age of 60 years, resulting in the fact that some of the persons were still employed and underestimated the time investment, although they were informed verbally and in written form at the earliest stage of the study. To prevent such undesired phenomenon, a decision to solely include retired persons (aged 67 years and older in Germany) could

Table 6 Changes in parameters of strength and performance-based tests of mobility-related activities after 24 weeks training in the intervention groups (IG1-IG3) and the control group (CG)

Variable	Protocol	Mean change	95 % CI	Change (%)	<i>p</i> Value	<i>f</i>	Power
Strength							
Isometric strength in leg press [N]	IG1	161.07 ^c	−5.89–328.03	+17	0.001*	0.43	0.77
	IG2	160.14 ^a	45.24–275.03	+18			
	IG3	161.16 ^c	−31.08–353.39	+17			
	CG	−125.4 ^a	−231.6–19.3	−13			
1RM test in leg press [kg]	IG1	11.2 ^{a, c}	−0.5–22.8	+11	0.002*	0.39	0.69
	IG2	17.3 ^{a, c}	6.2–28.4	+16			
	IG3	5.5	−4.1–15.2	+5			
	CG	−11.8 ^c	−22.5–1.1	−11			
Isometric strength in chest press [N]	IG1	44.6	−1.3–90.4	+7	0.002*	0.39	0.68
	IG2	49.41 ^a	−8.45–107.28	+8			
	IG3	−3.71 ^{a, b}	−106.64–99.21	0			
	CG	−92.7 ^{a, c}	−172.10 to −13.31	−12			
1RM test in chest press [kg]	IG1	8.0 ^{a, c, b}	4.8–11.3	+27	<0.001*	0.47	0.87
	IG2	9.4 ^{a, c, b}	5.9–12.9	+26			
	IG3	3.5 ^c	−0.3–7.4	+8			
	CG	−0.9	−3.7–1.9	−2			
Performance-based tests of mobility-related activities							
MSOT, habitual speed [s]	IG1	−1.1 ^{a, c, b}	−1.7 to −0.5	+16	<0.001*	0.51	0.92
	IG2	0.2	0.1–0.4	−3			
	IG3	0 ^{a, b}	−0.4–0.3	0			
	CG	0.2	−0.2–0.5	−3			
MSOT, maximal speed [s]	IG1	−1.0	−1.5 to −0.5	+17	<0.001*	0.57	0.97
	IG2	0.2	0–0.4	−4			
	IG3	0.1	−0.2–0.4	−2			
	CG	0.1	0–0.3	−2			
Chair Rise Test (CRT) [s]	IG1	−2.5 ^{a, c, b}	−3.4 to −1.6	+28	0.001*	0.41	0.75
	IG2	−1.3 ^{c, b}	−1.9 to −0.6	+12			
	IG3	−1.6 ^{a, c}	−2.6 to −0.6	+13			
	CG	−1.0 ^{a, c}	−2.1–0.1	+9			
Timed Up & Go Test (TUG) [s]							
TUGnorm	IG1	−1.1	−1.7 to −0.4	+16	0.053	0.29	0.41
	IG2	−0.4	−0.8–0	+7			
	IG3	−0.3	−0.8–0.1	+5			
	CG	−0.1	−0.4–0.3	+1			
TUGcog	IG1	−1.2 ^{a, b, c}	−1.9 to −0.5	+15	<0.001*	0.46	0.84
	IG2	−0.7 ^{a, c}	−1.3–0.1	+10			
	IG3	0.2 ^b	−0.4–0.8	−3			
	CG	0 ^{a, b}	−0.5–0.6	0			
TUGmot	IG1	−0.8 ^{a, c}	−1.1 to −0.4	+11	<0.001*	0.48	0.87
	IG2	0	−0.2–0.2	0			
	IG3	0.2 ^b	−0.2–0.6	−3			
	CG	0	−0.3–0.4	0			
Maximal Step Length Test (MSLT) [cm]							

Table 6 continued

Variable	Protocol	Mean change	95 % CI	Change (%)	<i>p</i> Value	<i>f</i>	Power
Right foot	IG1	9.9 ^{a, c}	6.3–13.6	+15	<0.001 [*]	0.48	0.87
	IG2	6.9 ^{c, b}	3.2–10.6	+9			
	IG3	0.6 ^{a, b}	−3.5–4.7	+1			
	CG	−2.3	−6.1–1.5	−3			
Left foot	IG1	10.0 ^{a, c}	6.8–13.2	+15	<0.001 [*]	0.42	0.77
	IG2	5.6 ^{a, b}	1.5–9.8	+7			
	IG3	2.2 ^a	−2.7–7.0	+3			
	CG	−2.1 ^b	−6.2–2.1	−3			

kg kilogram, *N* newton, *s* seconds, *cm* centimeters, *IG* intervention group, *CG* control group, *IRM* one-repetition maximum, *CRT* chair rise test, *MSOT* multisurface obstacle test for older adults, *TUG* timed up & go test, *TUGnorm* normal version, *TUGcog* with an additional cognitive task, *TUGmot* with an additional motor task, *MSLT* maximal step length test, mean change from baseline to 24 weeks, *CI* confidence interval, *change* + means improvement, − means decline, *p*-values refer to the interaction between time and group from two-factor repeated-measures ANOVA

* significant interaction ($p < 0.05$)

^a significant change between T1 and T2 ($p < 0.05$)

^b significant change between T2 and T3 ($p < 0.05$)

^c significant change between T1 and T3 ($p < 0.05$); *f* = effect size

be a solution or to implement a program like Granacher et al. (2011) within the working environment of younger adults.

In the resistance training section of the FuMoC, both hypertrophy and power were considered in the exercise regimen that was recommended by Cadore and Izquierdo (2013) to achieve enhanced improvements in performance-based tests of mobility-related activities. In this study, two phases of 8 weeks of hypertrophy training and 4 weeks of power training in each case were implemented. However, the combination of hypertrophy with power training could not be the reason for higher improvements in the performance-based tests of mobility-related activities because the two training groups with identical resistance and balance exercises (IG1 and IG2) had the same resistance exercise regimens. Therefore, it can be assumed that the track with movements of everyday life and uneven surfaces that was embedded into the FuMoC training program as active rest between the sets can provide an explanation for the advantage compared to the training group (IG2) without the track. Nevertheless, it could also be that the sole presence of an active rest alone was responsible for higher improvements because participants of IG2 obtained inactive rest. To clarify with certainty, the rest for IG2 also would have had to be active with an activity such as walking around without specific uneven surfaces and obstacles within a track. In this field of research, there is still a lack of information. From the authors' knowledge, there is no study that investigated different characteristics of active rest within resistance training and its impact on performance-based tests of mobility-related activities.

In the study presented here, as a first step, all interested persons were considered with the aim to reach a healthy, fit and homogeneous sample. As results of this study showed, compliance was very high, with the highest rate for IG1. Increasing attendance rates concerning the comparison of training phase one and two are indicative of increasing participant motivation and a well-designed training program, especially of the FuMoC (highest compliance). The results did not differ using training attendance as a covariate. Due to this, the presence of a possible dose response relationship could be neglected. Perhaps, training intensity and difficulty (within the training program) have to be enhanced for such a fit sample; however, with the presentation of all details of the exercise regimen and parameters to control the training in the FuMoC, various adaptations of the original form of this new training program are conceivable.

Persons suffering from gait disorders and balance problems have a higher risk to fall. This target group was intentionally excluded in the study presented here to have no further influencing factors. However, this can also be seen as selection bias because training in the FuMoC could perhaps yield more positive effects in fall endangered persons having gait disorders or balance problems. In the future, frailer older adults at a higher risk to fall should be incorporated; therefore, an adjusted version of the FuMoC could be implemented as a fall prevention program. If one takes into account elements of the FuMoC (strength, balance, movements of everyday life), it could be recognized that several aspects of the training components to positively influence fall-related risk factors are included in the

FuMoC as it has been done in several other fall prevention programs (American Geriatrics Society 2011; Becker and Rapp 2011; Gillespie et al. 2012; Granacher et al. 2011; Pizzigalli et al. 2011; Tiedemann et al. 2011).

In conclusion, this RCT demonstrated that training in the FuMoC led to positive effects on strength and performance-based tests of mobility-related activities. Some advantages of training in the FuMoC compared to the two other traditional training programs were present; however, these first findings have to be further researched. The detailed description and presentation of all exercises, components of the movement execution, and the parameters to control the load during training are important features of a comprehensive training program in the FuMoC. With this information, the FuMoC training program can easily be further adapted for application in frailer more fall endangered older adults. Therefore, the FuMoC should also be modified in accordance with current recommendations of falls prevention. To allow a generalization of effects achieved through training in the FuMoC, larger samples with various preconditions should be investigated to strengthen the clinical meaning of such findings. The sooner older adults (here age 60 years and older) begin to counteract age-related decreases through, e.g., training in the FuMoC, the longer they could maintain a spectrum of movements of everyday life (e.g., rising from a chair, climbing stairs, and walking). In addition, muscle strength, muscle power, and balance that are necessary for effectively preventing falls in high age would be extended.

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