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Diverse Exercises Similarly Reduce Older Adults' Mobility Limitations

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ABSTRACT

TOLLÁR, J., F. NAGY, M. MOIZS, B. E. TÓTH, L. M. J. SANDERS, and T. HORTOBÁGYI. Diverse Exercises Similarly Reduce Older Adults' Mobility Limitations. *Med. Sci. Sports Exerc.*, Vol. 51, No. 9, pp. 1809–1816, 2019. **Introduction/Purpose:** Little is known about the comparative effectiveness of exercise programs, especially when delivered at a high intensity, in mobility-limited older adults. We compared the effects of 25 sessions of high-intensity agility exergaming (EXE) and stationary cycling (CYC) at the same cardiovascular load on measured and perceived mobility limitations, balance, and health-related quality of life in mobility-limited older adults. **Methods:** Randomized to EXE (n = 28) and CYC (n = 27), mobility-impaired older adults (age 70 yr) exercised five times per week for 5 wk at 80% of age-predicted maximal heart rate. Waitlisted controls did not exercise (n = 28). **Results:** Groups did not differ at baseline in any outcomes ($P > 0.05$). The primary outcomes (The Short Form-36-Health Survey: EXE, 6.9%; effect size, 2.2; CYC, 5.5%, 1.94; Western Ontario and McMaster Universities Osteoarthritis Index: EXE, −27.2%, −3.83; CYC, −17.2, −2.90) improved similarly ($P > 0.05$). Secondary outcomes, including body mass (−3.7%), depression (−18%), and walking capacity (13.5%) also improved ($P < 0.05$) similarly after the two interventions. Activities of daily living, Berg Balance Score, BestTest scores, and Dynamic Gait Index improved more ($P < 0.05$) after EXE than CYC. Center of pressure of standing sway path improved in one of six tests only after EXE ($P < 0.05$). Postexercise cardiovascular response improved in EXE ($P = 0.019$). CON did not change in any outcomes ($P > 0.05$). **Conclusions:** When matched for cardiovascular and perceived effort, two diverse high-intensity exercise programs improved health-related quality of life, perceived mobility limitation, and walking capacity similarly and balance outcomes more in mobility-limited older adults, expanding these older adults' evidence-based exercise options to reduce mobility limitations.
Key Words: AGING, EXERCISE, GAIT, BALANCE

Up to 60% of individuals older than 65 yr report limitations in their abilities to walk, climb stairs, and perform usual and household activities (1). Mobility limitations are associated with increased risks for dependency, poor quality of life (QoL), disability, mortality, and a reduced survival rate (2–4). Although there is extensive evidence that diverse exercise interventions are effective and can improve healthy older adults' walking speed and potentially prevent the evolution of mobility disability (5), much less is known about the comparative effectiveness of such programs, especially when delivered at a high intensity, in mobility-limited older adults who tend to be physically unfit (6). In large-scale intervention studies, mobility-limited older adults responded well to low-intensity and low frequency training comprising aerobic, resistance, and flexibility exercises, reduced mobility limitations and the risks for developing mobility disability and transiently increased spontaneous physical activity (7,8). However, such benefits did not always reduce limitations in activities of daily living (ADL) (9) and these studies also did not compare the effectiveness of different types of interventions designed to reduce mobility limitations and improve QoL. Such information is needed because there is variation between older adults in the causes of mobility limitations. Of these causes, reduced lower-extremity muscle power is a key contributor to slow walking speed, making it an intervention target (10,11). However, strength and power training-induced increases in leg strength and power correlate poorly with increases in gait speed and balance (11) and the gait-speed increases in mobility-limited older adults often remain below the 0.1 $m \cdot s^{-1}$ threshold of functional significance (12,13). Indeed, mobility-limited older adults might be able to more effectively improve walking and balancing abilities and reduce mobility impairments when interventions target mobility and gait skills instead of muscle strength and power, as patients could more readily incorporate these skills into ADL (14,15).

Exergaming (EXE) is an inventive method to develop mobility skills of older adults with and without mobility

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impairments or neurological conditions but its comparative efficacy remains unclear (16). We developed an EXE program that targets multisensory functions, balance, proprioception, and spatial orientation through multijoint coordinative movements (17). As recommended, patients execute these movement sequences in a dynamic, explosive manner (18) at a high intensity, which has not yet been used by mobility-impaired older adults. Indeed, recently there has been a paradigm shift from low toward high-intensity exercise in older adults with and without motor impairments. For example, there are now explicit recommendations for prescribing exercise at a high intensity for Parkinsonian patients, including sensory-rich EXE (17,19) and for older adults using plyometric (18,20) and high-intensity interval training (21). These approaches combine cardiovascular stress, motor fitness, and sensory simulation and predict safe, rapid, and lasting adaptations in motor function such as mobility. We therefore hypothesized that a sensory-enriched, intense exercise stimulus, that is, EXE, would address the variation in dysfunction of the systems that underlie mobility limitations and would improve gait, balance, ADL, and—as a summary outcome—QoL. However, we also consider an alternative hypothesis that mobility-limited older adults have low levels of physical fitness so that any increases in physical fitness would already provide a sufficient stimulus to improve these older adults' abilities to walk, balance, perform ADL, and perceive increases in QoL. Indeed, a previous study reported support for the alternative hypothesis in Parkinson's patients (22). To test these hypotheses, we compared the effects of two fundamentally different exercise modalities: Exergaming that is rich in visual, auditory, and proprioceptive stimuli, a stimulus that also improves fitness and seated cycling (CYC) that is poor in such stimuli but is known to improve physical fitness and mobility. The purpose of this comparative effectiveness randomized trial was to determine the effects of 25 sessions of high-intensity agility EXE and stationary CYC at the same cardiovascular load on health, behavioral, and mobility outcomes in mobility-limited older adults.

METHODS

Participants and design. Participants referred by family physicians to the hospital with mobility difficulties and medical conditions were consecutively sampled from the hospital's database. The catchment area for referral was about 10 km (6 miles) of the hospital, located in the city center. Participants who appeared eligible (n = 97) based on medical records attended orientation and were familiarized with the EXE program, the cycle ergometers, and performed selected exercises slowly (Visit 1). Nine did not meet inclusion criteria and five declined to participate. Eighty-three (44 female) participants were included in the study. Inclusion criteria were: age, older than 60 yr, hospital referral from the family physician for a specific medical condition, including mobility difficulty. Exclusion criteria were: Mini Mental State Examination score >24, Beck Depression Inventory (BDI) score >40, severe cardiac disease, uncontrolled diabetes, history of stroke, traumatic brain injury, seizure disorder, Parkinson's disease, ongoing orthopedic surgeries, pacemaker, hemophilia, use of steroids or opioids for pain, walking aids, or participation in an exercise program. The frequency of treated medical conditions was as follows: hypertension, 62; diabetes, 47; fall-related injuries, 31; obesity, 26; disc herniation, 24; osteoporosis, 21; knee osteoarthritis, 17; knee ligament injuries, 15; gastroenterological problems, 10; chronic obstructive pulmonary disease, 8; and hip replacement, 6. Twenty-nine participants took a combination of five of more of these drugs for: blood pressure (BP, 11 types), diabetes, osteoporosis, arthritis, digestive and respiratory conditions, or other. Sixty-one percent took pain medications. The University Hospital's Ethics Committee approved the protocol and the informed consent, which each participant signed.

During the week before (visits 2–3) and after (visits 29–30) the interventions (visits 4–28), participants were tested over 2 d using the same testing schedule. The order of the motor tests was standardized among participants and testing sessions. Two physical therapists (PT) and an assistant administering the tests were masked to group assignments.

In a single-blind trial, participants were randomized into EXE, CYC, or waitlist control (CON) (Fig. 1). Two PT and an assistant administered the interventions but none of the tests. To minimize treatment bias, EXE and CYC changed in separate locker rooms and exercised in different rooms with independent entrances but at about the time of the day. None of the participants received PT for the 2 yr preceding the start of the study. The interventions were conducted in three 5-wk-long waves. CON did not exercise.

Mobility limitation. Being two standard deviations below the age, sex, and race-referenced healthy norm values (male, 564 m; female, 494 m), computed from regression questions reported in six studies for the 6-min walk test (6MWT), was defined as mobility disability (23).

Primary outcomes. Perceived general health-related QoL (The Short Form-36-Health Survey [SF-36]) and perceived mobility limitation measured by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). These outcomes are reliable, valid, and sensitive to changes induced by exercise intervention (21,24,25).

Secondary outcomes. Body mass, Schwab-England Activities of Daily Living scale (SE-ADL) to measure ADL limitations, BDI, 6MWT, a valid and reliable measure of walking capacity in mobility-limited elders (26), Balance Evaluation Systems Test (BESTest), a valid and reliable (R > 0.90) test to asses six domains of balance control; Berg balance scale (BBS), a valid and reliable (R = 0.80) test to assess fall risk, Dynamic Gait Index (DGI), a valid and reliable (R > 0.84) tool to asses gait adaptability, and postural stability by the magnitude of center of pressure (COP) path in standing on a force platform in a wide, narrow, and tandem stance with eyes open or closed for 20 s after one familiarization trial in each condition. HR and BP were measured and mean arterial pressure (MAP) computed after 5 min of seated rest before and after each session.

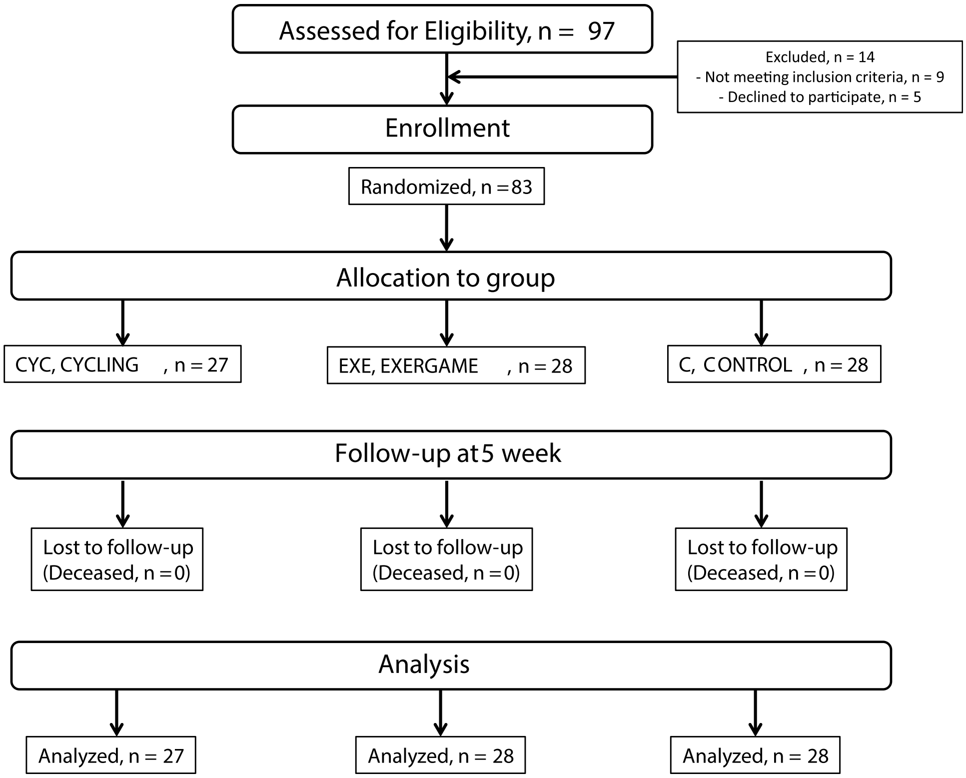

FIGURE 1—Consort diagram.

Interventions. The interventions (25, 1-h sessions, 5 d, 5 wk) were conducted in the hospital's PT gym. Up to three PT, trained and supervised by the principal investigator, delivered the interventions for groups of four to eight participants. Polar monitors on the chest recorded HR in each participant and session to match cardiovascular load in EXE and CYC. Target HR (80% × 220 − age) was paired with auditory cues from the Polar monitors and provided feedback every minute if HR deviated from the target > ±5%. Borg's RPE was recorded at end of every 5 min. Each 60-min session started with a 5-min warm-up, followed by 45 min of EXE or CYC, concluded with a 5-min cool-down and included 5 min of rest as needed during the 45-min segments (17). Warm-up consisted of walking on toes, heels, inside, and outside of the sole with and without hand-held apparatuses (rods with small weighted ball at the end, jogging, and stretching in sitting, lying, and standing.

As detailed previously (17), EXE used three Xbox 360 modules, 15 min each: Reflex Ridge trains reflex responses to visual stimuli; Space Pop trains spatial orientation through target reaching with arms, legs, and whole body, and Just Dance prompts users to generate and combine movement sequences. The EXE was designed to improve postural control, gait mobility, gait stability, turning, and balance (see Table, Supplemental Digital Content 1, Description of the EXE program, http://links.lww.com/MSS/B585).

In a "spinning class," CYC participants rode a bicycle ergometer at target HR, received no visual feedback, and listened to music. Five-minute bouts were interspersed with 1 min of freewheeling with the purpose to improve cardiovascular fitness.

Waitlisted CON continued habitual activity and could enroll in EXE after the study. All participants were explicitly and repeatedly asked not to change their diet, medication, and exercise habits while in the study and were asked to keep a diary of their diet, medication, and daily (physical) activities. Participants filled in the diaries concerning the symptoms associated with exercise immediately after each session in the locker room and at the end of the week concerning diet, medication use, and physical activity.

Statistical analyses. Setting GPower statistical software (University of Düsseldorf, Germany) to $\alpha = 0.05$, $1 - \beta = 0.8$, three groups, estimated $r = 0.5$ between repeated measures, 79 participants were needed for a significant group–time (pre, post) interaction in the primary outcomes. We also used an iterative modeling to estimate sample size needed to achieve at least a medium effect size of 0.50 for the primary outcomes. For SF-36, a change of 3.0 points (±7.0) due to the intervention and a change score of −1.0 (±6.0) for the control group indicated the need for 27 participants per group for the interaction to be significant. The analysis for the WOMAC indicated the need for 25 participants per group.

Data are expressed as mean ± SD (SPSS, v22). The variables were normally distributed based on the Shapiro–Wilk test. We compared EXE, CYC, and CON at baseline using a one-way ANOVA. One-way ANOVA on the gains scores compared EXE, CYC, and CON. A significant effect, characterized by $p\eta^2$ effect size (ES), was interpreted as a group by time interaction and was followed by a Tukey's *post hoc*. Within group changes were further quantified by Cohen's ES (small, 0.20; moderate, 0.50; large, 0.80). The Holm method was used to correct for family-wise error. Conditional process mediation (Process macro; 5000 bootstrap samples, bias-corrected confidence intervals) determined if changes in variables mediated the effects of EXE and CYC versus CON in key outcomes. The level of significance $P < 0.05$.

RESULTS

Baseline. The EXE, CYC, and CON did not differ at baseline in the outcome measures (Table 1).

Exercise intensity. Measured during each of the 25 exercise sessions, the RPE and HR were similar in the two intervention groups (RPE: EXE, 13.4 ± 1.57; CYC, 13.5 ± 1.69, P = 0.561; HR: EXE, 120.2 ± 6.07; CYC, 120.4 ± 5.60, P = 0.462).

Primary outcomes. Improvements in SF-36 did not differ between EXE (6.9%; ES, 2.2) and CYC (5.5%; ES, 1.94, Table 2). These changes exceeded the 0.9% (ES, 0.27) change in CON. Improvements in WOMAC did not differ between EXE (−27.2%; ES, −3.83) and CYC (−17.2; ES, −2.90) but were greater than the 1.7% change in CON (ES, 0.00). Figure 2 shows the distribution of individual changes in the primary outcomes and in selected secondary outcomes.

Secondary outcomes. Body mass decreased similarly (P > 0.05) in EXE (−3.7% ± 1.93%; ES, −1.17) and CYC (−3.7% ± 2.48%; ES, −0.89), and these reductions exceeded the 0.1% (±1.30) change in CON. The BDI scores decreased in EXE (−19.9% ± 15.35%; ES, −1.79) and CYC (−15.8% ± 15.70%; ES, −1.62), and these changes exceeded the 5.5% (±20.8) change in CON. The 7.3% (±9.79; ES, 1.79) improvement in the SE-ADL in EXE exceeded (P < 0.05) the changes in CYC (−1.0% ± 9.98%; ES, −0.26) and CON (−2.2% ± 9.90%, both P > 0.05).

The 6MWT distance increased (P < 0.05) similarly (P > 0.05) in EXE (13.8% ± 12.64%; ES, 1.29) and CYC (12.5% ± 9.61%; ES, 1.60), and these increases exceeded (P < 0.05) the changes in CON (−0.7% ± 11.43%; ES, −0.17) (Fig. 2). The EXE's improvements in BBS (30.7% ± 21.20%; ES, 3.98) (Fig. 2), BESTest (10.2% ± 6.40%; ES, 3.47), and DGI (13.2% ± 14.2%; ES, 1.95) exceeded the changes in CYC (ES range, 0.29–0.84) and CON (ES range, 0.00–0.45). The COP path decreased only when participants in EXE stood in a wide stance with eyes open (ES, –2.18; P < 0.05).

Mediation. Decrease in body mass and increase in 6MWT in EXE and CYC versus CON mediated directly and indirectly improvements in SF-36 (P < 0.05; see Document, Supplemental Digital Content 2, Mediation analysis, http://links.lww.com/MSS/B586). In EXE only but not in CYC versus CON, improvements in DGI, BBS, and BESTest mediated (P < 0.05) improvements in SF-36.

Chronic and acute effects of exercise on HR and BP. Measured after 5 min of seated rest before and after each of the 25 sessions, resting HR did no change in either group (P > 0.05). Preexercise SPB did not change (P > 0.05) but systolic BP measured after each of the 25 sessions decreased more in EXE (4.2 mm Hg; ES, 0.55) compared with CYC (0.8 mm Hg; F = 5.8, P = 0.019, $p\eta^2$ = 0.100). Preexercise MAP did not change (P > 0.05) but MAP measured after each of the 25 sessions decreased more in EXE (3.9 mm Hg, ES: 0.61) compared with CYC (0.5 mm Hg, F = 7.9, P = 0.007, $p\eta^2$ = 0.129).

Diet, medication, and activity diaries. A qualitative analysis of the diaries revealed no substantial changes in diet,

TABLE 1. Group characteristics at baseline.

Variable	EXE, *n* = 28/14 M	CYC, *n* = 27/12 M	CON, *n* = 28/13 M	All, *N* = 83/39 M
Age, yr	69.2 ± 2.80	70.2 ± 4.08	69.5 ± 3.67	69.6 ± 3.53
Height, cm	173.4 ± 6.75	173.1 ± 6.20	174.4 ± 6.44	173.6 ± 6.42
Mass, kg	72.5 ± 6.19	73.0 ± 8.13	75.3 ± 6.85	73.6 ± 7.10
BMI, kg·m^{-2}	24.3 ± 3.01	24.4 ± 2.79	24.8 ± 2.66	24.5 ± 2.80
SF-36	79.8 ± 6.84	80.3 ± 6.40	80.9 ± 5.38	80.3 ± 6.17
WOMAC total score	40.7 ± 6.48	40.6 ± 5.76	39.3 ± 6.58	40.2 ± 6.25
HR, bpm	82.5 ± 4.81	81.3 ± 5.53	81.9 ± 4.80	81.9 ± 5.02
SBP, mm Hg	125.9 ± 7.55	126.4 ± 7.62	127.5 ± 4.62	126.6 ± 6.68
DBP, mm Hg	84.6 ± 4.13	84.3 ± 4.37	83.9 ± 3.62	84.3 ± 4.01
MAP, mm·Hg	97.1 ± 3.35	96.1 ± 3.56	97.4 ± 3.18	96.9 ± 3.37
MMSE	27.5 ± 0.71	28.5 ± 0.70	27.6 ± 1.17	27.6 ± 1.08
BDI	12.4 ± 3.00	12.4 ± 2.80	11.0 ± 2.48	11.9 ± 2.81
SE-ADL, %	77.5 ± 5.85	79.3 ± 6.16	80.7 ± 6.63	79.2 ± 6.29
6MWT, m	325.7 ± 70.15	333.0 ± 57.63	343.6 ± 65.95	334.1 ± 64.51
BBS	27.4 ± 4.45	26.6 ± 5.81	26.9 ± 4.83	27.0 ± 5.00
BESTest	76.3 ± 4.70	76.7 ± 4.71	77.9 ± 4.37	77.0 ± 4.59
DGI	21.3 ± 1.83	21.0 ± 2.99	21.9 ± 1.96	21.4 ± 2.31
COP path, cm				
Wide stance, EO	5.3 ± 2.23	4.6 ± 2.29	4.4 ± 1.76	4.8 ± 2.11
Wide stance, EC	7.1 ± 2.14	6.5 ± 2.97	7.6 ± 4.58	7.1 ± 3.38
Narrow stance, EO	8.1 ± 3.12	7.0 ± 3.59	7.9 ± 5.25	7.7 ± 4.08
Narrow stance, EC	8.7 ± 3.49	8.6 ± 4.55	8.9 ± 3.12	8.7 ± 3.72
Tandem stance, EO	10.6 ± 3.21	9.8 ± 3.72	10.5 ± 3.72	10.3 ± 3.53
Tandem stance, EC	9.9 ± 4.16	10.5 ± 4.10	10.7 ± 6.55	10.4 ± 5.03

Values are mean ± SD.

n/M, number of participants/males; BMI, body mass index; SPB, systolic BP; DBP, diastolic BP; MMSE, mini mental state examination; BDI, Beck depression inventory (0–20, lower values, less depression); 0–100, 100 = no mobility disability; BBS, 0–20, 21–40, 41–56, respectively, high, medium, low fall risk; BESTest: maximum, 108, lower values, higher stability; DGI, maximum 24 < 19 predicts falls; EO, eyes open; EC, eyes closed.

TABLE 2. Gain scores of the outcome variables in the three groups.

Variables	EXE	CYC	CON	$F_{2,83}$	*P*	pη^2	*Post hoc* Comparisons
Mass, kg	−2.7 ± 1.46	−3.0 ± 2.05	0.1 ± 1.05	69.5	0.001	0.44	CON vs EXE, CYC
SF-36	5.0 ± 5.66	4.2 ± 4.45	0.7 ± 3.84	6.7	0.002	0.14	CON vs EXE, CYC
WOMAC	−11.6 ± 8.62	−7.1 ± 5.73	0.0 ± 8.40	16.1	0.001	0.29	CON vs EXE, CYC
BDI	−2.7 ± 2.23	−2.1 ± 2.06	0.4 ± 2.02	16.6	0.001	0.29	CON vs EXE, CYC
SE-ADL, %	5.4 ± 7.44	−1.1 ± 7.51	−2.1 ± 7.87	7.9	0.001	0.17	EXE vs CYC, CON
BBS	7.8 ± 4.81	2.5 ± 5.39	0.9 ± 5.36	13.4	0.001	0.25	EXE vs CYC, CON
BESTest	7.6 ± 4.68	1.1 ± 5.80	0.3 ± 4.92	17.2	0.001	0.30	EXE vs CYC, CON
DGI	2.6 ± 2.82	0.5 ± 2.62	−0.9 ± 3.30	10.3	0.001	0.21	EXE vs CYC, CON
6MWT, m	40.3 ± 35.67	37.3 ± 25.22	−5.1 ± 35.85	17.1	0.001	0.30	CON vs EXE, CYC
COP path, cm							
Wide, EO	−2.0 ± 3.04	−0.4 ± 2.85	0.9 ± 2.86	6.8	0.002	0.15	EXE vs CYC, CON
Wide, EC	−1.9 ± 2.48	−0.2 ± 3.50	−0.8 ± 3.94	1.6	0.210	0.04	
Narrow, EO	−3.2 ± 3.81	−1.4 ± 3.69	−0.6 ± 5.65	2.4	0.102	0.06	
Narrow, EC	−3.7 ± 4.43	−1.7 ± 6.64	−1.7 ± 4.65	1.4	0.249	0.03	
Tandem, EO	−2.4 ± 3.17	−1.6 ± 3.79	−0.8 ± 5.21	1.0	0.374	0.02	
Tandem, EC	0.3 ± 6.38	1.0 ± 5.53	0.6 ± 6.32	0.1	0.923	0.00	

Values are mean ± SD (posttest scores minus pretest scores in absolute units).
F, Group effect on the gain scores; *P*, all *P* values survived the Holm's correction for family wise error; pη^2, partial eta squared, denoting effect size.

medication, and daily physical activity. EXE and CYC frankly recorded their daily sessions and the information in CON also suggested no pattern of changes in these variables.

DISCUSSION

The results support the alternative hypothesis: when matched for cardiovascular load and perceived effort, EXE and CYC improved general health-related QoL (SF-36), perceived mobility limitation (WOMAC), and walking capacity similarly (6MWT, Table 2). The data provide evidence for exercise to have a general effect on health and mobility-related QoL and walking capacity, with evidence for some specificity of these effects on balance outcomes.

Level of mobility limitation. All 83 participants had mobility limitations, as they covered only 334 m at ~0.9 m·s^{-1}, below the approximately 1.3 to 1.4 m·s^{-1} age-normative value in healthy older adults (Table 1) (5). Using measurement conditions similar to ours, the walking distance is also far below the age-, sex-, and race-matched norm of 530 m based on data from six studies (23) or the 500-m norm (27). Thus, our older adults had a substantial level of mobility limitation.

Primary outcomes. In tandem with the level of mobility limitation and poor walking capacity, our participants' general health-related QoL was similar to age- and sex-matched SF-36 norms of approximately 70 points in mobility-limited elders (28). Compared with the four to five points of changes (Table 2), SF-36 scores improved up to 14 points after orthopedic surgeries (29), representing more serious medical events than the mobility limitation in our participants. Still, the four to five points of improvements suggest substantial reductions in risks for hospitalization and mortality because one-point change was associated with up to 12% reductions in such risks in diabetic patients (30). Mediation analyses revealed that body mass and 6MWT were the key variables accounting for improvements in SF-36 (see Document, Supplemental Digital Content 2, Mediation analysis, http://links.lww.com/MSS/B586). The approximately 7 to 12 points of

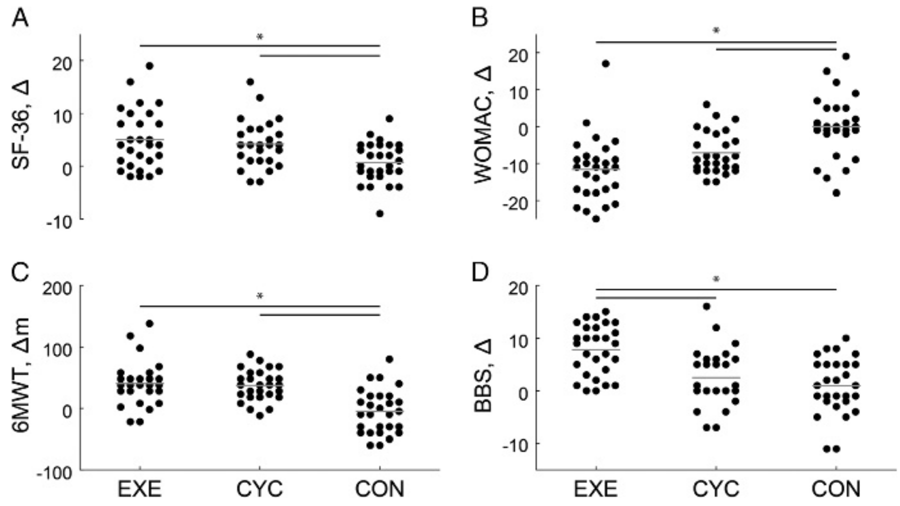

FIGURE 2—Individual changes (Δ) in health-related QoL (A), mobility disability (B), walking capacity (C), and balance (D). The *horizontal lines* within the data scatters denote the mean values and the *horizontal lines* above the data points show the differences (P* < 0.05) between EXE, CYC, and CON.**

improvements in WOMAC (Table 2) are in line with the changes normally seen after exercise therapy in patients with knee osteoarthritis (31). We did not see preferential changes in any of the subscales of SF-36 and WOMAC (data not shown). In summary, participants' perception of their QoL related to health and mobility limitation improved functionally meaningfully and independent of the type of intervention.

Changes in secondary outcomes. Walking capacity (6MWT) improved similarly after the two interventions by ~39 m (Table 2). In heart failure patients of the same age and sex distribution and 6MWT distance (341 m) (32) as our participants (334 m, Table 1) and also in healthy older adults (33), a change of 50 m was considered 'real' but in both cases for much larger sample sizes than ours. Aerobic, resistance, leg muscle power, walking, and combination exercise training increased 6MWT distance by an average of 36 m in nine studies of healthy older adults (5). Thus, we consider the approximately 39-m increase in 6MWT as reflecting substantial and functionally meaningful increase in walking capacity (26). The uniform increase in walking capacity after a program that targeted at similar cardiovascular and perceived effort sensorimotor skills requiring complex and coordinated movement series through EXE and a program that comprised invariant movements through seated CYC, is unexpected. However, the data are consistent with a general exercise effect in Parkinson's patients showing improvements in mobility independent of exercise type (22). A meta-analysis also reported numerically identical, 0.12 $m \cdot s^{-1}$, increases in healthy older adults' gait speed after resistance, coordination, and combination training (5). A meta-analytical umbrella review found no evidence for preferential effects of exercise type on mobility outcomes in mobility-limited elders (34). Thus, exercise programs, regardless of type, improved the fitness of our very low-fit participants (334 m 6MWT, Table 1), which in turn improved walking capacity and dynamic balance. Another factor that might have contributed to the improved walking capacity is the sizeable reduction in depression (Table 2), which tends to increase executive function (35) and self-efficacy. The emerging picture is that most older adults with or without mobility limitation will probably respond to any form of exercise interventions and improve walking capacity, providing flexibility in the individualization of exercise prescription.

We observed specificity favoring EXE versus CYC in improving dynamic but not static balance, an observation also borne out by the mediation analysis (see Document, Supplemental Digital Content 2, Mediation analysis, http://links.lww.com/MSS/B586). Participants' baseline BBS score of 27 (Table 1) was one half of the age-based norms (27), suggesting balance dysfunction in addition to impaired walking capacity. The greater improvements in BBS after EXE (~8 points) compared with CYC (~5 points, Table 2) suggest that the agility program was more specific in correcting balance problems, confirmed by the similar pattern of changes in the BESTest and DGI, suggesting internal consistency in these findings. Multifocal and sensory-enriched exercise stimulus by EXE is effective for correcting mobility-limited elders' balance problems albeit the exact composition, dose, and the superiority of such programs compared with conventional balance programs are still unclear (16).

In contrast to current practice (6,34), the present study used, for the first time, a high-intensity and high-frequency exercise program in mobility-limited elders. Such an approach is also becoming favored to treat Parkinsonian symptoms of which many are present in mobility-limited older adults (17,19). In contrast to low-intensity programs, the hope is that a focal and intensive exercise stimulus can reduce the number of nonresponders, activate neuroprotective mechanisms, allow participants to acquire motor skills faster, retain the skills longer, transfer the skills more successfully to ADL (Table 2, SE-ADL) (15), and more consistently and lastingly improve motor independence and QoL. Although such a program is expected to elicit substantial adaptations in cardiovascular function, the short-duration of our program, and the prevalence of hypertension (75%) and polipharmacy (35%) could have diminished cardiovascular adaptations.

Limitations. One limitation is the short study duration but when normalized for the number of sessions, outcome gains in longer studies are often similar to the gains reported in studies as short as the present work, suggesting a ceiling in the responses to the exercise stimulus (6,34). Without a detraining phase, we cannot tell how long the effects would last. Without a maintenance program, we cannot tell if the interventions-induced acute gains in mobility could be maintained and slow progression of mobility limitation. The small sample size prevented us to perform sex-stratified analyses. The substantial, 2.7 kg, reduction in body mass implies that participants might have modified their diet, physical activity, or both, which we did not monitor and analyzed only qualitatively based on diaries. Although the 100% adherence and 0% dropout suggest that high exercise intensity is feasible and well tolerated by in mobility-limited older adults, specially trained therapists delivered exercise sessions in a designated hospital facility, conditions unavailable elsewhere. However, patients could perform agility exercises or cycle on an ergometer at home with remote supervision, reducing costs and staff burden (36). Because current EXE modules do not quantify the duration, intensity, and the number of repetition of a given exercise within a program, it is not possible to determine if cardiovascular stress or motor fitness is behind the improvements in mobility. Without neural, biomechanical or neuropsychological markers, we were unable to determine the mechanisms of adaptations to EXE and CYC and if these mechanisms differed between the two programs.

CONCLUSIONS

When matched for cardiovascular and perceived effort, two diverse high-intensity exercise programs improved health-related QoL, perceived mobility limitation, and walking capacity similarly and balance outcomes more in mobility-limited older adults, expanding these older adults' evidence-based exercise options to reduce mobility limitations.

The authors declare no conflict of interest. The authors state that the results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The present study does not constitute endorsement by ACSM.

The study was registered as a clinical trial (NCT03427762).

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