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Gait speed response to aerobic versus resistance exercise training in older adults

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Abstract

Background—Little is known about the comparative effect of aerobic training (AT) versus resistance training (RT) on gait speed, a strong predictor of disability.

Aims—To compare the effect of AT versus RT on gait speed and other functional measures.

Methods—Overweight and obese [body mass index (BMI) ≥ 27.0 kg/m²] sedentary men and women aged 65–79 years engaged in 5 months of either 4 days/weeks moderate-intensity treadmill walking, AT, ($n = 44$) or 3 days/weeks moderate-intensity RT ($n = 56$). Usual-pace gait speed, fast-pace gait speed and short physical performance battery (SPPB) were evaluated in all participants before and after training. Peak oxygen consumption (VO_{2peak}) was assessed in AT participants only, and knee extensor strength was assessed in RT participants.

Results—Both AT and RT resulted in clinically significant improvements in usual-pace gait speed (0.08 ± 0.14 and 0.08 ± 0.17 m/s, respectively, both $p < 0.05$) and SPPB (0.53 ± 1.40 and 0.53 ± 1.20 points, both $p < 0.05$) and chair rise time (-1.2 ± 3.2 and -1.7 ± 3.0 s, $p < 0.05$). Only AT improved fast-pace gait speed (0.11 ± 0.10 m/s, $p < 0.05$). In the RT participants, lower baseline knee strength was associated with less improvement in usual-pace gait speed. In AT participants, lower baseline VO_{2peak} was associated with less improvement in chair rise time and self-reported disability.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the Rebecca M. Henderson states that there is no conflict of interest.

Human and animal rights All procedures performed in this study involving human participants were in accordance with the standards of the ethic committee of the local university and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individuals prior to participating in the study.

Discussion—While both AT and RT improved usual-pace gait speed, only AT improved fast-pace gait speed. Lower baseline fitness was associated with less improvement with training.

Conclusion—Research to directly compare which mode of training elicits the maximum improvement in older individuals with specific functional deficits could lead to better intervention targeting.

Keywords

Physical function; Gait speed; Aerobic training; Resistance training

Introduction

The speed at which one walks, both at a usual-pace gait speed (UGS) or at a fast-pace gait speed (FGS), decreases with age and is a strong predictor of progression to disability and mortality [1–4]. Gait speed, which depends on multiple physiologic systems, reflects an individual's general health and has been proposed as an additional vital sign in older adults [2, 5]. FGS begins to decline in about the third decade of life, while UGS speed remains stable until about the sixth decade before beginning to decline [6]. The rate of decline in both UGS and FGS continues to increase through the ninth decade of life [7], and the speed of this decline further predicts mortality [8, 9]. Approximately, one-quarter of well-functioning older adults experience a rapid decline in UGS, 0.03 m/s/year, which is a harbinger of increasing mortality [9]. However, Hardy et al. [5] observed that even transient improvements in gait speed decrease mortality risk. Therefore, interventions that maintain or increase gait speed in older adults may also increase life and health span.

Exercise training interventions improve physical function, including gait speed [10–13]. However, there is considerable controversy over which interventions, either those geared toward improving muscular strength via resistance training (RT) or improving aerobic capacity through aerobic training (AT) confer greater functional benefit in older adults. Previous reviews report substantial improvements in UGS with RT or RT/AT combined programs [11–13]. However, two recent reviews report that combining RT with other forms of training (including AT) may lessen improvements in gait speed from RT alone [14, 15]. Furthermore, there is minimal information on AT only interventions with regard to gait speed in older adults [16]. The two meta-analyses that examined effects of exercise training on FGS found contradictory results, one showing no improvement in FGS and the other showing substantial improvement (0.12 m/s) in FGS following exercise training [11, 15]. Despite all of the prior research on the functional benefits of RT and AT, there are surprisingly few direct comparisons between RT and AT on gait speed and other measures of function in older adults [17–23]. Thus, the primary purpose of this analysis was to compare the magnitude of changes in gait speed and other measures of lower-extremity physical function, between AT and RT in older, overweight/obese adults. To better understand the inter-individual variability in gait speed response to AT and RT, which can range from large improvements to small declines in persons with similar exercise adherence [24], we also analyzed whether baseline peak aerobic capacity was predictive of gait speed response to AT and whether baseline muscle strength was predictive of gait speed response to RT.

Methods

Study participants

This retrospective analysis of two exercise intervention studies included older (65-79 years), overweight and obese (body mass index [BMI] 27–45 kg/m²), sedentary men and women enrolled in either a 5-month aerobic training study (AT, $n = 61$) or a 5-month resistance training study (RT, $n = 63$) [24, 25]. Participants underwent an initial phone screening and those eligible underwent a subsequent medical history, physical examination and physical function assessments. Participants in the AT group completed a graded exercise stress test and those in the RT group completed an isokinetic knee extensor strength test. Both studies were approved by the Wake Forest School of Medicine Institutional Review Board, and all participants provided written informed consent.

Participants were recruited from Forsyth and surrounding counties through media advertisement and mass mailings. All participants met the following criteria: nonsmoking for past year; normal cognitive function; and no evidence of clinical depression, heart disease, cancer, liver or renal disease, chronic pulmonary disease, uncontrolled hypertension, physical impairment, or any contradiction to exercise. The inclusion criteria differed only for BMI range (30–45 kg/m² for AT and 27–34.9 kg/m² for RT) and the definition of sedentary (<20 min 2 days/week of exercise for AT and no resistance training in the past 6 months for RT).

Exercise interventions

All exercise sessions were center based and supervised by study staff, including at least one exercise physiologist, who provided oversight while monitoring for adherence to exercise frequency, duration and intensity. Heart rate and blood pressure were monitored and recorded before and after each exercise session.

Aerobic training—Participants exercised 4 days/week on treadmills. Each training session began with a warm-up for 5 min at a slow pace and ended with a 5-min cooldown followed by light stretching. Participants walked at an intensity of 65–70 % of heart rate reserve [HRR, assessed during the peak aerobic capacity (VO_{2peak}) test]. The duration of exercise progressed from 15 to 20 min at 50 % HRR the 1st week to 30 min at 65–70 % HRR by the end of the 6th week and thereafter. At least two heart rate readings (measured by Polar heart rate monitors) were taken during each session to monitor compliance to the prescribed exercise intensity. Treadmill speed and grade were adjusted individually to insure that participants exercised at their prescribed exercise intensity.

Resistance training—Participants group exercised 3 days/week on Nautilus resistance machines. Each training session began with an initial warm-up by walking or cycling for 5 min at a slow pace and concluded with a 5-min cooldown and light stretching. The machines used during each session were: (1) leg press; (2) leg extension; (3) seated leg curl; (4) seated calf; (5) incline press; (6) compound row; (7) triceps press; and (8) bicep curl. The protocol involved a gradual progression in the weight lifted, and the number of sets completed during the 1st month to allow participants to familiarize themselves with the equipment, minimize

muscle soreness and reduce potential for injury. The maximal weight that a person could lift with correct form in a single repetition (1RM) was used to prescribe intensity. The training goal was for participants to complete 3 sets of 10 repetitions at 70 % 1RM for each exercise. The weight was increased when a participant was able to complete 10 reps on the 3rd set for 2 consecutive sessions. Strength testing was repeated every 4 weeks and the training loads adjusted to be consistent with the 70 % 1RM goal.

Assessments

All testing at baseline and follow-up was completed at our Geriatric Research Clinic by study personnel who are trained in the standardized conduct of all assessments. The VO_{2peak} test was only conducted in the AT study, and the isokinetic knee extensor strength test was only conducted in the RT study.

VO_{2peak} was determined on a motorized treadmill during a graded exercise test to exhaustion using a ramp protocol as previously described [26]. The treadmill speed was held constant as the grade increased at small intervals throughout the test. Valid tests achieved two of the following three criteria: (1) plateau in oxygen consumption with increasing workload (<200 ml/min); (2) respiratory exchange ratio >1.10; and (3) maximal heart rate >90 % of age-predicted maximal heart rate.

Maximal isokinetic knee extensor strength was measured via an isokinetic dynamometer (Biodex) at 60°/s with the participant sitting and the hips and knees flexed at 90°. Participants were asked to extend the knee and push as hard as possible against the resistance pad. Strength of the dominant leg recorded as peak torque in Newton-meters (Nm) was used for analyses. Standardized verbal encouragement was provided to the participant while performing the test.

Lower-extremity function was assessed using the Short Physical Performance Battery (SPPB) [27]. The SPPB consists of three physical performance measures including a standing balance test (holding a side by side, semi-tandem and tandem position for a maximum of 10 s), usual-pace gait speed over a 4-m course and time to complete five repeated chair stands without use of the arms. Results from each of the three tests are scored with 0 indicating inability to perform the test to 4 indicating highest function. Scores from the three tasks are summed for the total SPPB score, which ranges from 0 (worst physical performance) to 12 (best physical performance).

Usual-pace gait speed (UGS) in m/s was obtained by converting the time to walk a 4-m course during the SPPB.

Fast-pace gait speed (FGS) was assessed using a 400-m walk test [28]. Participants were instructed to complete the 400-m distance (on a flat indoor surface 20 m in length) as quickly as possible, and the time to complete the walk was recorded in seconds and converted to m/s. Encouragement was given in a standardized fashion every lap.

Self-reported disability was measured using a 23-item questionnaire which inquires about perceived difficulties in general activities of daily living during the last month [29]. Respondents answer whether they experience: (1) no difficulty, (2) a little difficulty, (3)

some difficulty, (4) a lot of difficulty, (5) unable to do or (6) did not do for other reasons, and answers are averaged across items.

Statistical analysis

Baseline characteristics were reported as mean $\pm$ SD (standard deviation) for continuous variables or as a frequency (percentage) for categorical variables by study. Comparisons of baseline characteristics were done using Student's *t*-test for continuous variables and Chi-square test for categorical variables. Absolute (post-training minus pre-training) and relative (percent) changes in physical function variables were calculated. Paired *t*-test was used to assess changes in response to each intervention within each study, and two-sample *t*-test was used to compare AT to RT. Analysis of covariance (ANCOVA) was also used to compare improvements in physical function between AT and RT participants, adjusting for age, gender, BMI and baseline measure. Least square means of physical function variables for each study and the differences between AT and RT were estimated from the ANCOVA model. Simple and partial Pearson correlation analyses were used to explore the baseline relationship of functional measures with VO₂peak in AT participants and with leg strength in RT participants. Multiple linear regression models were used to examine the relationship of functional response (absolute change and percent change) to baseline VO₂peak in AT and to baseline leg strength in RT participants. Regression coefficients were estimated from the regression models. All analyses were performed using SAS 9.4 (Cary, NC). Significance level was set at 0.05.

Results

Baseline characteristics and retention/adherence

On average, baseline age, race, blood pressure and comorbidities were similar between participants in AT and those in RT (Table 1). However, there were more females in the AT group and, by design of the inclusion/exclusion criteria for each study, the body mass and BMI were higher in AT. Thus, at baseline, gait speed and all other measures of physical function were worse in participants enrolled in AT versus RT (Table 1). A total of 44 participants completed the AT intervention and 56 completed RT. Overall adherence to the prescribed frequency of exercise sessions was similar for AT and RT (AT = 84 %; RT = 86 % of sessions attended).

Changes in physical function within and between AT and RT

Table 2 shows average unadjusted absolute and relative changes in gait speed and other functional outcomes. All objective measures of physical function improved significantly with both AT and RT, except FGS, which improved only with AT. Self-reported disability did not improve in either group. As expected, the AT group showed significant improvements in VO₂peak ($p < 0.01$) and RT resulted in significant improvements in knee extensor strength ($p < 0.01$).

Table 3 shows the least squares means and 95 % CIs for post-intervention measures of physical function (adjusted for age, gender, BMI and baseline value). The adjusted post-

intervention values for UGS, SPPB and chair rise time were similar between AT and RT. However, compared to RT, AT elicited significantly greater improvement in FGS ($p < 0.05$).

Baseline associations

We examined the cross-sectional relationships between the measures of lower-extremity function and the physiologic measures of peak aerobic capacity in the AT participants and muscle strength in the RT participants. In the AT group, FGS ($r = 0.63$, $p < 0.0001$), UGS ($r = 0.44$, $p < 0.01$) and SPPB ($r = 0.33$, $p < 0.05$) all correlated with VO_{2peak} . Self-reported disability tended to be better in those with a higher VO_{2peak} ($r = -0.25$, $p = 0.08$), but there was no relationship between baseline chair rise time and VO_{2peak} . All of these relationships became non-significant after adjustment for age, sex and BMI.

In the RT group, FGS ($r = 0.56$, $p < 0.0001$), UGS ($r = 0.39$, $p < 0.01$), SPPB ($r = 0.26$, $p = 0.04$) and self-reported disability ($r = -0.42$, $p < 0.001$) were associated with knee extensor strength. Chair rise time ($r = -0.24$, $p = 0.06$) tended to negatively correlate with knee extensor strength at baseline. After adjustment for age, gender and BMI, FGS (Pearson partial $r = 0.30$, $p < 0.05$) and self-reported disability (Pearson partial $r = 0.37$, $p < 0.01$) were still significantly associated with knee extensor strength.

Relationship of baseline VO_{2peak} to changes in gait speed and other functional measures in response to AT

We next analyzed whether individuals with lower peak aerobic capacity at baseline experienced greater improvements in gait speed and lower-extremity function with AT. After adjustment for age, gender, BMI and baseline physical function value, changes in both chair rise time and self-reported disability were significantly related to VO_{2peak} at baseline, so that, participants with lower baseline aerobic fitness experienced less functional improvement. Table 4 provides the adjusted values. In addition, improvement in FGS with AT tended ($p = 0.09$) to be less in those with lower aerobic fitness at baseline.

Relationship of baseline leg extensor strength to changes in gait speed and other functional measures in response to RT

We also examined whether individuals with less leg strength at baseline experienced greater gait speed and functional improvements with RT. After adjustment for age, gender, BMI and baseline physical function value, changes in UGS and chair rise time were associated with leg extensor strength at baseline, such that participants who were weaker experienced less improvement in UGS and chair rise time (Table 4).

Discussion

There are limited data comparing the effectiveness of AT and RT on gait speed or other measures of function particularly in overweight, or obese older adults. The primary purpose of this study was to determine whether one mode of exercise leads to a greater improvement in UGS, FGS and other functional measures, using a retrospective analysis of combined data from two independent studies in older, overweight/obese adults. We found both AT and RT

resulted in similar, clinically significant [29], improvements in UGS (0.08 m/s), SPPB (0.5 points) and chair rise time (>1 s). However, only AT improved FGS (0.11 m/s).

Two previous reports [17, 20] seem to support our finding that AT induces greater improvement in FGS than does RT. Middle-aged and older adults with knee osteoarthritis in the AT arm of the Fitness Arthritis and Seniors Trial (FAST) study appeared to have a larger improvement in 6-min walk distance than those in the RT arm (1507 ft with AT vs 1406 ft with RT; 1.28 vs 1.19 m/s), though these were not statistically compared by the authors [17]. Roma et al. [20] similarly report greater improvements in FGS with AT than RT. However, atypically, they also report UGS improvements with AT, but not with RT.

Our findings do conflict with several other studies. Sipila et al. [30] reported similar increases in FGS with both AT and RT. However, FGS was measured over a short distance (10 m) compared to our study (400 m) and appeared to have a ceiling effect since the final gait speed in all groups was >1.8 m/s. Another study comparing AT and RT also showed a small improvement in FGS with both AT and RT, but no difference between groups [18]. However, the RT intervention was center based, supervised and had higher adherence and the AT (walking) intervention was home based, unsupervised and had lower adherence. This may explain why UGS did not change with RT and declined with AT. A study in patients recovering from hip fracture repair found improvements in FGS and UGS with both RT and AT, but also in their control group, with no difference between groups [22]. Holviala et al. [21] found that AT, RT or combined training (AT and RT) all improved FGS after 10½ weeks, but by study end (21 weeks), this improvement was only maintained in the RT and combination groups. However, FGS was assessed over a short distance (10 m) and was conducted with a 10.2-kg bag in each hand, which may explain why only the individuals participating in RT showed continued improvement.

We recently documented the wide inter-individual variability in functional responses to both AT and RT in this same cohort of older adults [24]. Since baseline functional status can influence the functional response to training, a secondary purpose of the present study was to determine whether baseline peak aerobic capacity or muscle strength was associated with functional responses to training. We previously showed in this cohort an indirect relationship between baseline UGS, chair rise time and SPPB and improvement following AT or RT (greater improvement in those with worse baseline function) [24]. We hypothesized, for the AT group, that participants with low $\text{VO}_{2\text{peak}}$ at baseline would show a larger gait speed response to AT than those with high baseline $\text{VO}_{2\text{peak}}$. However, our results showed the opposite, in that those with lower aerobic fitness at baseline experienced less improvement in FGS (as well as chair rise time and self-reported disability) in response to AT. Similarly, for the RT group, we hypothesized that participants with lower muscle strength at baseline would show greater gains in gait speed with RT than those with higher baseline strength. However, participants who were weaker at baseline experienced less improvement in UGS and chair rise time in response to RT. Our finding, of less improvement in more impaired individuals, is supported by two studies that found after AT (walking interventions), older adults with lower baseline functional measures had less improvement [31, 32]. On the contrary, two studies show that with RT, greater improvement was seen in those with lower functional measures at baseline [33, 34]. Our analysis differs from the above studies in that

we used baseline aerobic fitness or strength to define level of impairment, while the other studies used less physiologic functional measures. To our knowledge, no other studies have reported the association between functional improvement and direct measures of baseline aerobic fitness or strength.

A significant limitation of this study is that the interventions were not directly compared in a randomized fashion in the same study population. Nor did we have strength measures in the AT group, or VO₂peak in the RT group. Therefore, we were unable to make any statements regarding their interaction within each training group.

In conclusion, both AT and RT improved UGS in previously sedentary, overweight or obese older adults; however, individuals with lower baseline aerobic fitness or muscle strength experienced less improvement in gait speed with AT or RT, respectively. It is not known why these individuals respond less to interventions targeted to their deficits, nor whether they would respond better to an alternative intervention. Research to directly compare which mode of training elicits the maximum improvement in older individuals with specific functional deficits could lead to better intervention targeting.

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Table 1

Baseline characteristics

	Aerobic training (<i>n</i> = 61)	Resistance training (<i>n</i> = 63)
Age (years)	69.1 (3.7)	69.4 (3.6)
Female no. (%)	46 (75 %)	34 (54 %) *
Whites no. (%)	46 (75 %)	54 (86 %)
Body mass (kg)	95.3 (13.7)	87.3 (13.1) *
BMI (kg/m ²)	34.5 (3.1)	30.7 (2.4) *
Systolic blood pressure (mmHg)	134 (14)	137 (23)
Diastolic blood pressure (mmHg)	74 (10)	76 (11)
Self-reported comorbidity		
Hypertension	36 (59 %)	29 (46 %)
Diabetes ^a	12 (19 %)	9 (14 %)
Sleep apnea	19 (31 %)	20 (32 %)
Arthritis	46 (75 %)	40 (64 %)
VO ₂ peak (ml/kg/min)	18.8 (3.3)	Not measured
Knee extensor strength (Nm)	Not measured	118.8 (39.6)
Physical function		
Usual-paced gait speed (m/s) ^b	1.00 (0.19)	1.15 (0.19) *
Fast-paced gait speed (m/s) ^c	1.23 (0.23)	1.33 (0.21) *
SPPB score (0–12)	10.2 (1.6)	10.9 (1.2) *
Chair rise time (s)	13.8 (3.4)	11.9 (3.2) *
Self-reported disability (1–5)	1.39 (0.36)	1.16 (0.21) *

Values are mean (standard deviation) or *n* (%)

Chair rise time: time for 5 consecutive chair rises as fast as possible

Self-reported disability: scale of 1 (“usually did with no difficulty”) to 5 (“unable to do”)

BMI body mass index

* Significantly different than AT, all *p* < 0.05

^a Non-insulin-treated diabetes

^b Over a 4-m course

^c Over a 400-m course

Table 2

Unadjusted changes in physical function with aerobic and resistance exercise training

	<u>Aerobic training</u>		<u>Resistance training</u>	
	Change	% Change	Change	% Change
Usual-paced gait speed (m/s)	0.08 (0.14)	8.6 (13.4)	0.08 (0.17)	7.9 (14.4)
Fast-paced gait speed (m/s)	0.11 (0.10)	9.0 (8.7)	0.00 (0.16) [†]	0.3 (12.1) [†]
SPPB score (0–12)	0.53 (1.40)	8.3 (24.1)	0.53 (1.20)	5.8 (12.8)
Chair rise time (s)	–1.2 (3.2)	–9.1 (22.2)	–1.7 (3.0)	–10.4 (25.7)
Self-reported disability (1–5)	–0.07 (0.37)	–2.9 (29.4)	0.02 (0.21)	2.0 (16.9)
VO ₂ peak (ml/kg/min)	1.44 (1.48)	7.8 (8.1)	–	–
Knee extensor strength (Nm)	–	–	11.5 (16.5)	10.1 (13.9)

[†]
 $p < 0.001$ compared to AT

Table 3

Model-adjusted post-intervention physical function least squares means and adjusted group differences and 95 % confidence intervals

Post-intervention value	AT	RT	AT–RT diff	<i>p</i> value
Usual-paced gait speed (m/s)	1.18 (0.03)	1.17 (0.02)	0.01 (0.04)	0.84
Fast-paced gait speed (m/s)	1.42 (0.03)	1.29 (0.02)	0.14 (0.03)	<0.001
SPPB score (0–12)	11.2 (0.2)	11.1 (0.1)	0.1 (0.3)	0.72
Chair rise time (s)	11.0 (0.4)	10.9 (0.3)	0.1 (0.6)	0.91
Self-reported disability (1–5)	1.22 (0.05)	1.26 (0.04)	–0.04 (0.07)	0.61

AT aerobic training, *RT* resistance training

Table 4

Relationship of physical function responses with baseline VO₂peak in aerobic training participants and baseline leg strength in resistance training participants

Physical function variable	Relationship with baseline VO ₂ peak		Relationship with baseline leg strength	
	Regression coefficient (SE)	<i>p</i> value	Regression coefficient (SE)	<i>p</i> value
Usual-paced gait speed	0.008 (0.008)	0.32	0.0020 (0.0010)	0.04
Fast-paced gait speed	0.012 (0.007)	0.09	0.0016 (0.0010)	0.12
SPPB score	0.082 (0.060)	0.18	0.009 (0.006)	0.13
Chair rise time	−0.409 (0.144)	0.01	−0.0267 (0.0129)	0.04
Self-reported disability	−0.052 (0.021)	0.02	0.0016 (0.0014)	0.27

Adjusted for age, gender, BMI and baseline value of each functional measure Bold values indicate significant *p* value (*p* < 0.05)