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Research article

EFFECT OF STRENGTH AND ENDURANCE TRAINING ON COGNITION IN OLDER PEOPLE

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ABSTRACT
The purpose of this study was to investigate the effect of moderate strength and endurance training on cognition evaluated by event-related potentials (ERP) in older people. Thirty-six adults, aged 60–85 years, were randomly divided into three groups: sedentary control (C), strength training (ST), and endurance training (ET). Participants performed functional fitness tests and ERP data were recorded before and after nine weeks of training. Training involved three sessions per week. Functional fitness test performance improved significantly in the ST and ET groups. The latencies of the N1, N2, and P2 components and the amplitudes of the N1P2, P2N2, and N2P3 components differed significantly between groups ($p < 0.05$). After training, the latencies of the P2 and N2 components at the Fz and Cz sites, decreased significantly, and the amplitudes of the N1P2, P2N2, and N2P3 components at the Fz site and the N1P2 and N2P3 components at the Cz site, increased significantly in the ST group compared with the ET group. After training, the latencies of N1, N2, and P2 components shortened significantly, and the amplitudes of the N1P2, P2N2, and N2P3 components increased significantly in the ST group compared with the C group. The latencies of the N2 and P2 components shortened significantly in the ET group compared with the C group, although the amplitudes of the ERP recordings did not differ significantly between groups. These data suggest that strength training might facilitate early sensory processing and cognitive functioning in older individuals.

KEY WORDS: Exercise training, cognitive function, aging, event-related potentials, functional fitness.

INTRODUCTION

Aging is a natural phenomenon characterized by loss of neurons and decrements in neurotransmitter release and physiological function (Dice, 1993; Yu, 1994). The aging process is accompanied by deterioration of cognitive functions such as memory, attention, reaction time, and speed of information processing (Van Boxtel et al., 1997). The neurotransmitter systems play an important role in the process of cognition, and deterioration of the transmitter systems causes cognitive decrement in aging.

A growing body of evidence suggests that physical exercise may have facilitating effects on general cognitive function during aging (Chodzko-Zajko and Moore, 1994; Hatta et al., 2005; McDowell et al., 2003; Polich and Lardon, 1997; Yagi et al., 1999). In the first well-controlled study of exercise training and cognition, Dustman et al. (1984) found that performance on some cognitive tasks is attenuated in participants with low physical fitness. Despite the implications of the finding that exercise can contribute to cognitive capability (intellectual performance), it is unclear whether the type of physical activity might influence cognition.

Recommendations have been published about the appropriate exercise prescription to maintain musculoskeletal fitness and reduce the risk of cardiovascular diseases such as atherosclerosis and coronary artery disease, which might contribute to healthy aging (ACSM, 1995; Brandon et al., 2000; Kasch et al., 1999; Pollock et al., 2000). Although aerobic exercise is more frequently recommended to increase cardiovascular fitness in older adults (Kasch et al., 1999), strength training is also highly recommended as an important component of the overall fitness program (Evans and Cyr-Campbell, 1997; Feigenbaum and Pollock, 1999; Hass et al., 2001; Pollock et al., 2000). Whereas previous studies have suggested that physical training affects cognitive performance in older subjects (Dustman et al., 1984; 1990; 1993; Polich and Lardon 1997), the literature does not address the question of whether different exercise regimens might contribute to the maintenance of cognitive capability.

Event-related potentials (ERPs) provide a non-invasive method to assess the function of the central nervous system (CNS) (Beck and Dustman, 1975). ERPs are electrical potentials elicited by a series of repeating stimuli such as flashes of light, clicks, or tones that the subject expects to fail. Because ERPs reflect processes that occur in the CNS between the stimulus and the response, they can provide information about the time course of cognitive processing in the brain. ERPs comprise a group of components involved in human cognitive processing that are usually identified by their polarity and sequence of occurrence (e.g., P3 specifies the third positive component following the stimulus onset) (Beck and Dustman, 1975).

ERPs can be evoked in various ways to study aging, including early-latency visual evoked potentials (VEP), brain stem auditory evoked potentials (BAEP), and somatosensory evoked potentials (SEP). ERP components extend over only a few milliseconds and provide information about the neural transmission of signals through the sensory relay stations in brain stem structures. Middle-latency components occur between 20 and 80 ms following stimulus presentation and reflect the arrival and initial processing of sensory input in the primary cortical receiving areas (Beck and Dustman, 1975). Long-latency components occur after about 80 ms and reflect characteristics of the subject's psychological state, for example, the level of arousal, attention, and habituation (Beck and Dustman, 1975; Picton et al., 1984; Regan, 1972).

Long-latency ERPs closely reflect cognitive functions such as stimulus-evaluation time (P3 latency) and task relevance (P3 amplitude). The latency of the P3 is acknowledged as a measure of information processing speed for attention, working memory, and subjective probabilities (Kügler et al., 1993). Long-latency ERPs have been studied extensively in normal elderly people and in individuals with brain pathology such as dementia, Alzheimer's disease, and Parkinson's disease (Raudino et al., 1997; Tandon and Majahan, 1999). Previous studies have shown that the P3 latency is influenced only by the degree of stimulus discriminability but not by the degree of difficulty in executing the motor responses. The factors that might influence the P3 amplitude are sensitive to variations in the sequence of the stimuli preceding the eliciting event, and are inversely related to both subjective expectancy and objective overall probability of event occurrence (Kügler et al., 1993).

Many studies have attempted to determine the effect of age on the P3 component, and whether this has diagnostic utility (Kügler et al., 1993; Polich, 2004; Ozgocmen et al., 2003; Yamaguchi and Knight, 1991). For example, the latency of P3 progressively increases in normal aging (Kügler et al., 1993). Men with a high VO_2max demonstrate earlier P3 latencies, greater P3 amplitude, and superior cognitive efficiency than men with lower physical fitness (Dustman et al., 1993). The purpose of this study was to determine the effect of different types of exercise training (moderate endurance and strength training) on cognitive performance evaluated by ERP recordings in older individuals.

METHODS

***Participant*s**

This study protocol was approved by the Akdeniz University Ethical Committee (approval number 26.12.2002/08). All participants had medical clearance to participate in the testing and training sessions. One hundred and twenty elderly, sedentary participants who did not engage in any physical training programs were assessed for eligibility (Figure 1). All signed an informed consent form before the testing and subsequent training. The participants were volunteers, between 60 and 85 years of age, who were healthy, living independently in a retirement home, performing daily living activities without mobility aids, and had a Standardized Mini-Mental State Examination (SMMSE) score $\geq$ 24. Seventy-six people were excluded: 21 because they had an SMMSE score $<$ 24, and 55 because of a previous history of stroke, diabetes, depression, hypertension, osteoarthritis,

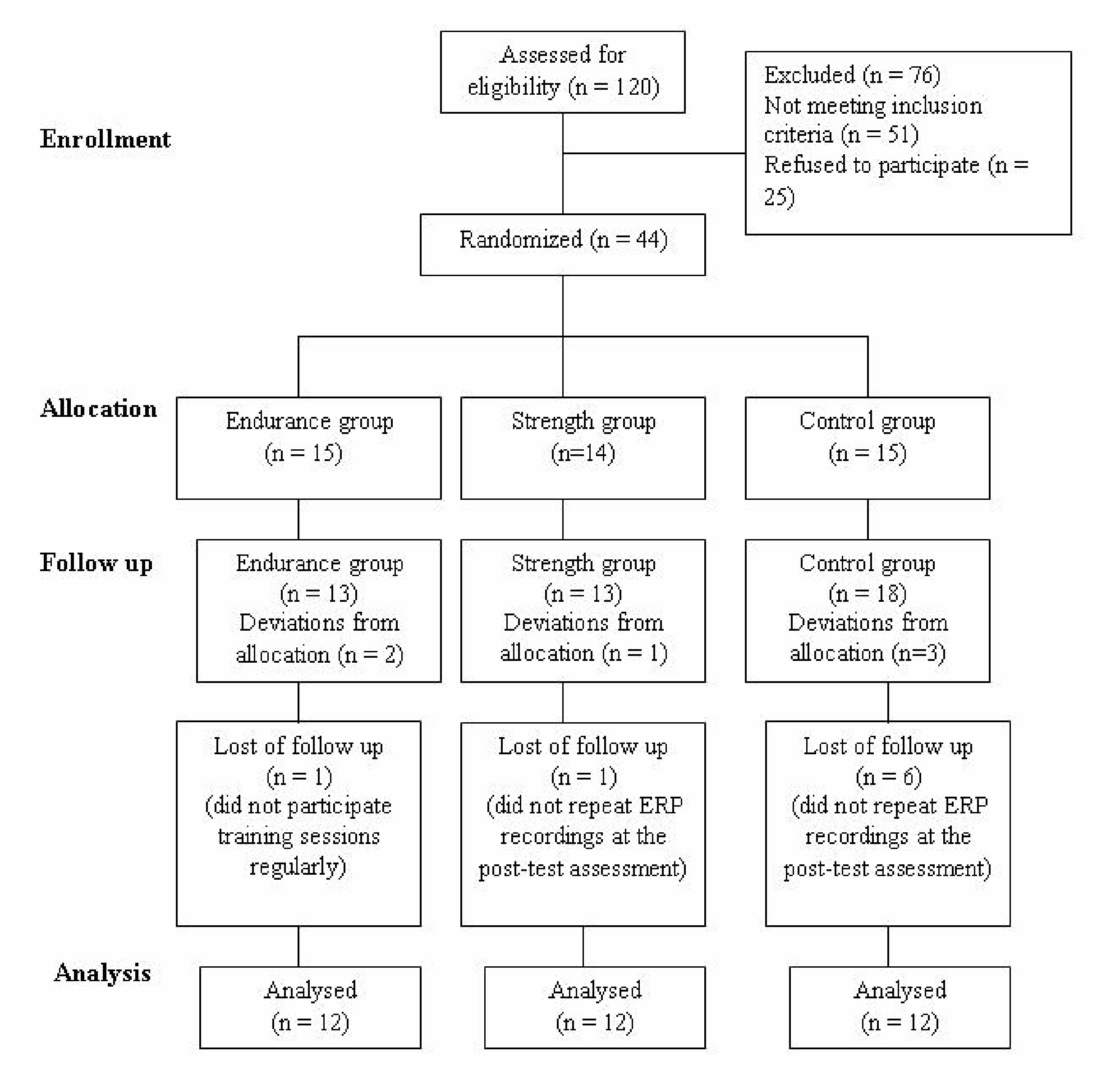

Figure 1. Procedure for randomized clinical trial.

chronic obstructive lung disease, visual or auditory impairment, and smoking habits. Forty-four of 120 individuals interviewed initially were included in the study; an additional 25 individuals did not wish to participate. The 44 adults (30 males, 14 females) accepted into the study were stratified by their sex and were randomly assigned to a control group (C), endurance training group (ET), and strength training group (ST). Two of the women in ET and one of the women in ST group preferred to stay in the C group, leaving 10 men and three women in the ET group, 10 men and three women in the ST group, and 10 men and eight women in the C group. Participants recruited as controls were asked not to participate in a formalized exercise program or to change their physical activity routine during the nine-week control period.

Clinical assessments included a thorough preventive medical evaluation that covered a personal and family health history, a physical examination, a questionnaire on demographic characteristics and health habits, resting electrocardiography, lung radiography, blood chemistry, and hematological tests followed by a consultation with a cardiologist and neurologist. Older participants who did not repeat all measures at the post-test assessment and who did not participate in three consecutive training sessions were excluded. Thirty-six non-smoking elderly adults completed the randomized trial.

Necessary information on functional ability, affective function, and cognitive ability was collected at baseline.

Functional ability: Functional ability is an indicator of physical function and reflects the level of an older adult's functioning in activities of daily living, instrumental activities of daily living, and mobility (DiPietro, 1996). Functional ability was assessed by self-evaluation, using the Turkish version of the Composite Physical Function Questionnaire (CPF) (Rikli and Jones, 1998). The test–re-test reliability of the Turkish version of the questionnaire was 0.93. Functional ratings were based on responses to a 12-item CPF scale asking participants to indicate their ability to perform common everyday activities ranging from personal care items such as bathing and dressing oneself (basic activities of daily living), to various household, gardening, walking, and lifting activities (activities needed to live independently within the community), to advanced activities such as moving heavy objects, sports, and aerobic dance activities (strenuous exercise). The scoring protocol for the CPF questionnaire required that participants check one of three responses: "can do" (score 2), "can do with difficulty or with assistance" (score 1), or "cannot do" (score 0) for each of the 12 items. Advanced functioning was defined as being able to perform all 12 items with no difficulty, moderate functioning as being able to perform seven of the 12 items with no difficulty, and low functioning as being able to perform six or fewer of the tasks with no difficulty or assistance (Rikli and Jones, 2001).

Affective function: Depressive symptomatology was assessed using the 30-item Geriatric Depression Scale (GDS) (Yesevage et al., 1983). The GDS was dichotomized into depressed or not depressed using the Standard cutoff ≥ 11 and < 11, respectively. However, we note that these cutoffs have not been validated fully with Turkish older adults.

SMMSE: Cognitive function was measured using the modified Turkish version of the SMMSE. The sensitivity of the scale was 92%, the specificity was 93%, and the inter-rater reliability was 0.99 (Güngen et al., 1999).

Outcome measures

The study was conducted between March 2003 and May 2003. The functional fitness tests and ERP recordings were performed two weeks before the start of the training program and repeated in the tenth week, after the training program had ended. The tests were administered by the same observers without reference to the baseline values. The order of testing was identical before and after training: the ERP recordings were performed first followed by the functional fitness tests. All recording and testing was performed in the morning between 08:00 and 11:00 h.

ERP procedures

Recordings were made in a sound-attenuated chamber adjacent to the computers, video monitors, amplifiers, and recorders. During electrophysiological testing, the participants sat in a comfortable chair 1 m in front of a monitor. Participants sat motionless and with eyes closed during the recordings of P3. During ERP monitoring procedure, vigilance was maintained at a constant level throughout the recording by alerting participants at 2 min intervals. The participants were familiarized with the two different tones and instructed to count the rare target tones silently before the P3 was recorded.

ERP recordings

Ag-AgCl electrodes were placed at Fz and Cz actively according to the international 10–20 system (Heinze et al., 1999), referenced to a linked earlobe electrode, and with a forehead electrode as a ground electrode. Impedances were maintained below 5 kΩ and were measured from each lead at the beginning and end of each session. P3 potentials were recorded with a Nihon-Kohden® Neuropack® 8 EMG/evoked-response measuring system MEB-4200K with a band-pass of 0.1–50 Hz. Recordings were made for 1000 ms, beginning at 100 ms prior to stimulus onset, with an amplification of 50 µV/unit sensitivity. P3 potentials were obtained from an auditory oddball paradigm. The 2 kHz target tones were presented with a probability of 20%, whereas the 1 kHz non-target tones were presented with a probability of 80% binaurally over headphones at a sound level intensity of 90 dB. Tone bursts were presented with an inter-stimulus interval of 2 s with 10 ms rise–fall times. Rare tones were presented randomly when the task was not presented more than three times consecutively. Responses of targets and non-targets were averaged separately. At the end of each session, each participant's count was compared with the actual number of target tones given to assess the accuracy of the task performance. All participants performed the tasks with an error rate < 5% in all trials.

Principal peaks and their identification were made according to the standard recommendations for long latency auditory event-related potentials of The International Federation of Clinical Neurophysiology and principal component analysis technique (Heinze et al., 1999). The N1, P2, N2, and P3 latencies and amplitudes were measured from peak-to-peak points of the N2 and P3 waves at Cz and Fz recordings. The P3 potentials obtained from target tones were evaluated. Peak latencies of N1, P2, N2, and P3 were measured using either the points at which the amplitude was highest or the extrapolated points when necessary. The amplitude of the P3 wave was measured as an absolute value between the peak points of N2 and P3 (N2P3). The neurophysiological values were averaged across Cz and Fz electrode positions in all participants.

Functional fitness

Functional fitness has been defined as having the physiological capacity to perform normal everyday activities safely, independently, and without undue fatigue. After a 10 min warm-up led by an exercise instructor, the participants completed the Senior Fitness Test items (Rikli and Jones, 2001), which have been validated by Rikli and Jones (Rikli and Jones, 1999a). All tests were administered in a group setting of up to 22 participants per group. To accommodate group testing, all test stations except the 6 min walk were set up "circuit" style in a gymnasium. Stations were arranged in the following order around the periphery of the gymnasium: chair stand, arm curl, height and weight, chair sit-and-reach, back scratch, and 8 ft (2.44 m) up-and-go. Immediately after the 10 min warm-up exercises, participants were evenly divided (four per group) and sent to one of the seven testing stations to begin their tests**.** Tests were administered at each station by one volunteer assistant, with the test coordinator overseeing the procedures and rotating the groups in clockwise order from one station to the next. The 6 min walk test was administered after all other tests had been completed.

The Senior Fitness Test consists of seven different assessments:

1. The chair-stand test was used to assess lower body strength. After a demonstration by the tester, participants completed a practice trial of two repetitions, followed by one 30 s test trial. The score was the total number of stands executed correctly within 30 s.

2. An arm-curl test was used to assess upper body strength. After a demonstration by the tester, participants completed a practice trial of two repetitions, followed by one 30 s test trial. The score was the total number of hand-weight curls performed through the full range of motion in 30 s.

3. Height was measured by using an ultrasonic height measure (Soehnle 5001, Soehnle-Waagen GmbH, Murrhardt, Germany) and body weight was measured with a Tanita Body Composition Analyzer (Model TBF-300 TANITA, Tokyo, Japan); body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

4. The chair sit-and-reach test was used to assess lower body flexibility. After a demonstration by the tester, participants performed two practice trials, followed by two test trials. The score was the best distance achieved between the extended fingers and the tip of the toe, measured to the nearest 1.3 cm.

5. A back-scratch test was used to assess upper body flexibility. After a demonstration by the examiner, participants performed two practice trials, followed by two test trials. The score was the shortest distance achieved between the extended middle fingers, measured to the nearest 1.3 cm.

6. An 8 ft up-and-go test was used to assess agility or dynamic balance. After a demonstration, participants performed one practice trial, followed by two test trials. The score was the shortest time to rise from a seated position, walk 0.31 m, turn, and return to the seated position, measured to the nearest 0.1 s.

7. A 6 min walk test was used to assess aerobic endurance. Participants performed one practice trial before the actual test, with a break of two days between the practice and test trials. The score was the total distance walked in 6 min along a 45.72 m rectangular course, which was marked every 4.57 m.

Exercise protocol

Participants participated in a nine-week exercise program that included training sessions three times per week. Training sessions began with a 10 min warm-up and ended with a 10 min cool-down period, which both included a slow walk followed by slow, static stretching. The ET group performed aerobic training on a running track, the ST group performed strength training, and the C group did not train. Each session was led by trained fitness instructors and supervised by the researchers.

Aerobic training: The training heart rate was established using the Karvonen method (Wilmore and Costill, 1994). The parameters used for the training were intensity (70% of heart rate reserve), and frequency (3 $d \cdot wk^{-1}$). The duration on day 1 was 20 min, which increased by 5 min each session until participants were walking for 50 min in wk 3. The training heart rate was monitored by determining the heart rate at the midpoint and end of each training session via a heart-rate monitor (Sport Tester PE 300, Helsinki, Finland).

Strength training: The participants performed one set of 12 repetitions of seven exercise stations in the first week, and three sets in the second week. The exercises included hip extension, knee flexion, seated lower-leg lift, chair squat, arm raise, biceps curl, and abdominal crunch. Familiarization sessions and one-repetition maximum (1RM) determination were performed before the first week of the training. 1RM was determined for each exercise as suggested by Rogers et al. (2003). After formal instruction in the use of weight-training equipment, participants performed each exercise several times at a low resistance to ensure proper warm-up and familiarization (free self-selected

Table 1. Baseline characteristics of the study subjects. Values are means (± standard error).

	Control group (n=12)	Strength group (n=12)	Endurance group (n=12)
Age (year)	72.3 (2.1)	75.8 (2.8)	70.9 (3.1)
SMMSE (score)	27.1 (.6)	25.6 (.7)	26.5 (.6)
Education (year)	8.0 (1.4)	7.9 (1.6)	10.1 (1.8)
Body Mass Index (kg·m^{-2})	29.5 (1.3)	31.2 (2.9)	29.1 (1.4)
Composite physical function (point)	18.7 (1.2)	19.8 (.9)	21.9 (.9)
Geriatric depression scale (point)	10.2 (.3)	9.8 (.3)	9.9 (.3)
Chair sit-and-reach (cm)	-9.3 (6.3)	-12.0 (4.5)	-6.1 (2.8)
Back scratch, cm	-16.7 (5)	-14.1 (4.8)	-6.4 (3.2)
Arm curl (reps)	16.8 (.8)	15.3 (1.4)	12.3 (1.0) *
Chair stand (reps)	12.1 (.9)	11.5 (1.0)	12 (.6)
8 ft up-and-go (sec)	8.6 (.9)	7.0 (.6)	6.2 (.5)
6-min walk (m)	338.2 (31.5)	359.0 (35.6)	430.5 (15.6)

* $p < 0.05$ compared with control group by ANOVA.

Abbreviation: SMMSE = Standardized Mini Mental State Examination, reps = number of repetitions.

weights such as dumbbell, sand bags, and weighted belt). Beginning weights ranged from 0.5 to 1.5 kg and weight increments were in the range of 0.5–7 kg, depending on the exercise, until the subject was unable to lift the additional weight with acceptable form despite verbal encouragement. Failure was defined as an inability of the subject to lift the weight through the entire range of motion on at least two attempts spaced 45–60 s apart. Lifts were discounted if the participant used momentum or changed body position in a manner not directly related to the movement of the weight during the exercise motion to minimize fatigue resulting from repetition, each test began at a weight near a predicted maximum, and the 1RM was identified with four to six repetitions. Two minutes of rest was allowed between trials to prevent premature fatigue. The order in which the 1RMs were performed was: hip extension, abdominal crunch, biceps curl, knee flexion, seated lower-leg lift, arm raise, and chair squat. Weight training began at 60% of 1RM and was gradually adjusted by 5% every 2 wk until participants lifted 80% of 1RM.

Statistical analysis

Data are expressed as means ± S.E.M. Data were analyzed using SPSS software (SPSS V. 10.0). $P < 0.05$ was considered significant. The absolute changes (postintervention–preintervention) on the Senior Fitness Test values, and the latencies and amplitudes of the ERP recordings were calculated for each subject. Analysis of variance (ANOVA) was used to compare the groups on baseline characteristics, functional fitness test scores, and ERP recording scores, and to compare changes between preintervention and postintervention. When the ANOVA was significant, Tukey *post hoc* tests were used to locate the significant differences. A paired *t* test was used to compare the mean preintervention and postintervention values from the ERP recordings for each group.

RESULTS

The primary aim of this study was to compare the effects of different types of training (moderate endurance and strength training) on cognitive performance in elderly participants.

The groups did not differ significantly at baseline for age ($p = 0.443$), cognitive function ($p = 0.289$), education ($p = 0.553$), BMI ($p = 0.725$), CPF ($p = 0.101$), or GDS ($p = 0.541$). The groups differed significantly at baseline on the arm-curl test [$F(2,33) = 4.596$, $p = 0.021$] (Table 1 and Table 2). *Post hoc* comparison of the arm-curl test score revealed higher scores in the C group than in the ET group ($p = 0.017$), while there were no differences between C and ST groups ($p = 0.578$) and also ST and ET groups ($p = 0.154$). The groups did not differ at baseline on scores for the chair sit-and-reach test ($p = 0.713$), back-scratch test ($p = 0.256$), chair-stand test ($p = 0.873$), 8 ft up-and-go test ($p = 0.069$), 6 min walk test ($p = 0.087$). The groups also did not differ significantly at baseline for the latencies of the N1 ($p = 0.992$), P2 ($p = 0.097$), N2 ($p = 0.771$), and P3 ($p = 0.555$) components at the Fz site, and the N1 ($p = 0.836$), P2 ($p = 0.053$), N2 ($p = 0.174$), and P3 ($p = 0.912$) components at the Cz site (Table 3). The groups did not differ significantly at the Fz site in the amplitudes of the N1P2 ($p = 0.301$), P2N2 ($p = 0.442$), and N2P3 ($p = 0.577$) components, and at the Cz site in the amplitudes of the N1P2 ($p = 0.525$), P2N2 ($p = 0.058$), and N2P3 ($p = 0.156$) components (Table 4). All participants were classified as having moderate functional ability. No accidents or medical complications related to

Table 2. Absolute changes (postintervention–preintervention) in functional fitness tests. Values are means (± standard error).

	Control group (n=12)	Strength group (n=12)	Endurance group (n=12)
Body Mass Index, kg·m^{-2}	.1 (.6)	-.1 (.3)	-.2 (.1)
Chair sit-and-reach (cm)	-2.0 (2.2)	8.3 (2.8) *	6.9 (1.4) †
Back scratch (cm)	-1.1 (.5)	6.4 (2.2) *	5.1 (.5) †
Arm curl (reps)	-2.9 (.6)	2.1 (.7) *	2.5 (.5) †
Chair stand (reps)	-.4 (.6)	2.5 (.3) *	1.9 (.4) †
8 ft up-and-go (sec)	.4 (.2)	-.4 (.4)	-1.2 (.4) †
6-min walk (m)	1.7 (9.8)	64.5 (24.2) *	56.4 (12.8)

* Difference between ST and C ($p<0.05$) as determined by ANOVA,

† Difference between ET and C ($p<0.05$) as determined by ANOVA,

Abbreviation: reps = number of repetitions.

directly to the training were observed.

Absolute changes in the senior fitness tests (postintervention–preintervention)

The absolute changes in the senior fitness tests are presented in Table 2. Training resulted in a significant difference in performance between the groups in the chair sit-and-reach [F(2,33) = 6.663, p = 0.005]; back scratch [F(2,33) = 9.819, p = 0.001]; arm curl [F(2,33) = 27.854, p < 0.001]; chair stand [F(2,33) = 10.583, p = 0.001]; 8 ft up-and-go [F(2,33) = 5.740, p = 0.010] and 6 min walk [F(2,33) = 4.561, p = 0.022]. The groups did not differ significantly for BMI [F(2,33) = 0.082, p = 0.922]. Post hoc analysis showed no significant differences between ET and ST in the chair sit-and-reach (p = 0.899), back scratch (p = 0.765), arm curl (p = 0.896), chair stand (p = 0.650), 8 ft up-and-go (p = 0.310), and 6 min walk (p = 0.937). In the ET group, training produced a significant improvement in performance in the chair sit-and-reach (p = 0.023), back scratch (p = 0.007), arm curl (p < 0.001), chair stand (p = 0.007), and 8 ft up-and-go (p = 0.007). Similarly, in the ST group, training improved performance in the chair sit-and-reach (p = 0.008), back scratch (p = 0.001), arm curl (p < 0.001), chair stand (p = 0.001) and 6 min walk (p = 0.030). 8 ft up-and-go performance did not differ between the ST and C groups (p = 0.182) and 6 min walk performance did not differ between the ET and C groups (p = 0.063). The C group showed no significant change in any variable.

Intraclass evaluation of ERP latencies

The latencies of the ERP components for all groups are presented in Table 3. The latency of the N1 component at the Fz and Cz sites was reduced in the ST group, (p = 0.016 and p = 0.005, respectively), and in the ET group (p = 0.03 and p = 0.003, respectively). The latencies of the P2, N2, and P3 components at the Fz and Cz sites did not change significantly in the ST and ET groups (p > 0.05). In the C group, the mean latencies of the N1, P2, N2, and P3 components did not change significantly at either the Fz or Cz site (p > 0.05).

Table 3. Latencies of ERP components of studied groups (ms). Values are means (± standard error).

Groups		**Fz**				**Cz**			
		N1	**P2**	**N2**	**P3**	**N1**	**P2**	**N2**	**P3**
Control	Initial	122.0	193.0	269.3	382.9	122.0	196.2	265.3	394.0
		(7.0)	(10.4)	(18.8)	(10.4)	(7.0)	(13.8)	(12.6)	(12.5)
	Final	115.0	202.9	255.6	392.0	119.0	200.2	259.8	392.1
		(7.4)	(13.0)	(9.9)	(16.4)	(4.8)	(12.3)	(10.0)	(19.9)
Strength training	Initial	123.3	207.9	261.8	401.9	128.6	207.4	271.2	391.7
		(8.7)	(3.3)	(9.6)	(16.5)	(14.6)	(17.5)	(15.2)	(19.9)
	Final	99.7	182.6	269.4	395.6	102.9	180.0	268.4	404.7
		(5.0) *	(4.0)	(15.6)	(11.2)	(3.3) *	(4.2)	(14.0)	(13.4)
Endurance training	Initial	122.9	182.4	255.7	374.9	120.9	173.3	250.6	389.8
		(6.0)	(10.5)	(9.1)	(11.9)	(7.1)	(7.4)	(9.7)	(16.9)
	Final	94.7	190.5	244.6	379.7	100.9	179.3	254.9	378.3
		(4.7) *	(9.6)	(17.3)	(20.0)	(4.7) *	(10.4)	(16.8)	(7.9)

* Significantly different ($p < 0.05$) from initial value as determined by paired *t* test.

Table 4. Amplitude values of ERP components of studied groups (μV). Values are means (± standard error).

Groups		Fz			Cz		
		N1P2	**P2N2**	**N2P3**	**N1P2**	**P2N2**	**N2P3**
Control	Initial	12.1 (.8)	5.9 (.7)	10.7 (1.1)	12.1 (1.0)	7.9 (1.7)	11.1 (.9)
	Final	11.3 (.9)	6.2 (.6)	11.4 (.7)	14.0 (1.5)	8.0 (.7)	11.8 (1.0)
Strength training	Initial	10.5 (1.3)	6.7 (1.1)	9.3 (.9)	10.7 (2.0)	8.1 (1.0)	12.3 (1.2)
	Final	17.9 (2.7)*	10.4 (1.7)*	14.1 (1.6)*	19.8 (3.2)*	9.7 (1.0)	15.1 (2.0)
Endurance training	Initial	11.2 (1.4)	7.4 (.6)	9.7 (.7)	9.9 (.9)	8.5 (1.8)	11.6 (1.1)
	Final	12.2 (1.5)	6.2 (.4)	13.7 (2.0)	12.4 (1.8)	7.1 (.8)	12.6 (2.1)

* Significantly different ($p < 0.05$) from initial value as determined by paired *t* test.

Absolute changes of ERP latencies (postintervention–preintervention)

The absolute changes of the latencies of the ERP components are presented in Table 5. The groups differed significantly at the Fz site in the latencies of the N1 component [F(2,33) = 3.335, p = 0.041], P2 component [F(2,33) = 8.111, p = 0.004], and N2 component [F(2,33) = 9.260, p = 0.002]. The groups also differed significantly at the Cz site in the latencies of the P2 component [F(2,33) = 9.756, p = 0.001] and N2 component [F(2,33) = 9.787, p = 0.001]. The groups did not differ significantly at the Fz site in the latency of the P3 component [F(2,33) = 0.020, p = 0.981]. The groups also did not differ significantly at the Cz site in the latencies of the P3 component [F(2,33) = 1.145, p = 0.112] and N1 component [F(2,33) = 2.582, p = 0.0.091].

Post hoc analysis showed significant differences between the ST and ET groups at the Fz site in the latencies of the P2 component (p = 0.032) and N2 component (p = 0.011), and at the Cz site in the latencies of the P2 component (p = 0.007) and N2 component (p = 0.002). The ST and ET groups did not differ significantly at the Fz site in the latency of the N1 component (p = 0.292).

In the ST group compared with the C group, training produced significant improvement in the latencies of the N2 and P2 components at the Fz site (p = 0.013 and p = 0.003, respectively) and at the Cz site (p = 0.027 and p = 0.034, respectively) The N1 latency at the Fz site was shortened in the ST group compared with the C group (p = 0.002).

The ET and C groups differed significantly in the latencies of the N2 component at the Fz site (p = 0.013) and the Cz site (p = 0.027), and the latency of the P2 component at the Fz site (p = 0.003). The groups did not differ significantly in the latencies of the N1 component at the Fz site (p = 0.061), and the P2 component at the Cz site (p = 0.066).

Intraclass evaluation of the ERP amplitudes

The amplitudes of the ERP components for all groups are presented in Table 4. In the ST group, the peak-to-peak amplitudes of N1P2 ($p < 0.001$), P2N2 (p = 0.027), N2P3 (p = 0.020) at the Fz site and N1P2 (p = 0.012) at the Cz site were significantly higher at postintervention than at baseline, while there were no differences in the peak-to-peak amplitudes of P2N2 and N2P3 at the Cz site ($p > 0.05$).

In the ET group, the peak-to-peak amplitude of N1P2 and N2P3 components at both the Fz and Cz sites were non-significantly higher and peak-to-peak amplitude of P2N2 at both the Fz and Cz sites were non-significantly lower at postintervention than at baseline levels ($p > 0.05$). The peak-to-peak amplitudes of all components at both sites did not change significantly in the C group ($p > 0.05$).

Table 5. Absolute changes (postintervention –preintervention) in latencies of the ERP components. Values are means (± standard error).

Groups	Fz				Cz			
	N1	**P2**	**N2**	**P3**	**N1**	**P2**	**N2**	**P3**
Control	-6.8 (10.1)†	52.8 (12.7)†‡	88.7 (18.2)†‡	9.1 (19.1)	11.1 (8.8)	23.6 (1.0)†	93.9 (14.5)†‡	11.0 (19.6)
Strength training	-23.5 (5.0)	-23.8 (6.6) *	-11.1 (13.5)*	-1.6 (22.4)	-25.6 (16.3)	-27.4 (16.6)*	-19.7 (25.7)*	-37.0 (29.9)
Endurance training	-25.9 (3.5)	5.9 (22.2)	-7.6 (18.2)	4.8 (26.9)	-20.0 (9.1)	6.1 (16.1)	21.2 (17.1)	7.0 (2.0)

* Difference between ET and ST group ($p < 0.05$) as determined by ANOVA.

† Difference between ST and C groups ($p < 0.05$) as determined by ANOVA.

‡ Difference between ET and C groups ($p < 0.05$) as determined by ANOVA.

Table 6. Absolute changes (postintervention–preintervention) in amplitudes of the ERP components. Values are means (± standard error).

Groups	Fz			Cz		
	N1P2	P2N2	N2P3	N1P2	P2N2	N2P3
Control	2.3 (2.4) †	.4 (.8) †	.4 (1.4) †	2.8 (1.5) †	.6 (1.6)	.1 (1.6) †
Strength training	8.3 (2.7) *	3.7 (1.9) *	4.8 (1.4) *	9.1 (4.0) *	1.6 (2.4)	2.8 (2.7) *
Endurance training	-.1 (1.6)	-1.3 (.6)	3.7 (2.4)	2.2 (2.1)	-1.6 (1.1)	.4 (2.3)

* Difference between ET and ST group ($p < 0.05$) as determined by ANOVA.

† Difference between ST and C groups ($p < 0.05$) as determined by ANOVA.

Absolute changes of ERP amplitudes (postintervention–preintervention)

The absolute changes of the amplitudes of the ERP components are presented in Table 6. The groups differed significantly at the Fz site in the amplitudes of the N1P2 component [F(2,33) = 8.601, p = 0.005], P2N2 component [F(2,33) = 3.979, p = 0.013], and N2P3 component [F(2,33) = 6.497, p = 0.021]. The groups also differed significantly at the Cz site in the amplitudes of the N1P2 component [F(2,33) = 9.240, p = 0.003] and N2P3 component [F(2,33) = 4.572, p = 0.010]. The groups did not differ significantly at the Cz site in the amplitude of the P2N2 component [F(2,33) = 0.743, p = 0.494].

At the Fz site, the absolute changes in the amplitudes of the N1P2 (p = 0.002), P2N2 (p = 0.038), and N2P3 (p = 0.044) components were greater in the ST than in the ET group. At the Cz site, the absolute changes in the amplitudes of the N1P2 (p = 0.007) and N2P3 (p = 0.024) components were greater in the ST than in the ET group.

At the Fz site, the absolute changes in the amplitudes of N1P2 (p = 0.011), P2N2 (p = 0.041), and N2P3 (p = 0.004) components were greater in the ST than in the C group. At the Cz site, the absolute changes in the amplitudes of the N1P2 (p = 0.003) and N2P3 (p = 0.010) components were greater in the ST than in the C group. The ET and C groups did not differ significantly at the Fz site in the amplitudes of the N1P2 (p = 0.206), P2N2 (p = 0.368), and N2P3 (p = 0.879) components, and at the Cz site in the amplitudes of the N1P2 (p = 0.638) and N2P3 (p = 0.057) components.

DISCUSSION

The aim of this study was to determine whether two types of exercise training would improve cognition or have different effects on cognitive processing in older people. The functional fitness tests showed significant improvements after training in the two trained groups, suggesting that the training programs were sufficient to cause an improvement in functional fitness in these participants.

Senior fitness tests

The absolute changes in performance in the functional fitness tests did not differ between the two training groups. The performance of both training groups improved significantly in the chair sit-and-reach, back-scratch, arm-curl, and chair-stand tests compared with the control group. The absolute change in performance on the 6 min walk test was greater in the ST than in the C group, and the absolute change in the 8 ft up-and-go test was higher in the ET than in the C group.

A high proportion of participants in all groups performed below the age- and gender-based population norms for these functional fitness tests (Rikli and Jones, 1999b). In the ET group, 50% were below the relevant norm on the arm curl and 8 ft up-and-go tests, 58% on the chair-stand and chair sit-and-reach tests, 33% on the back-scratch test, and 75% on the 6 min walk test. In the ST group, 42% were below the relevant norm on the arm-curl test, 67% on the chair-stand and 8 ft up-and-go tests, 75% on the back-scratch test, and 83% on the 6 min walk and chair sit-and-reach tests. In the C group, 33% were below the relevant norm on the arm-curl test, 58% on the chair-stand test, 92% on the 8 ft up-and-go test, 83% on the back-scratch test, 67% on the chair sit-and-reach test, and 100% on the 6 min walk test. The lower performance on all tests suggests that these participants were unfit, so the differences from the published norms probably resulted from the participants' poor fitness.

Although the participants in the two exercise groups exercised in a supervised and controlled setting, the improvements in all functional fitness tests were small, especially for the chair-stand and arm-curl tests. The improvements in the arm-curl test and chair-stand test in the ST group were much lower than should be expected with nine weeks of training. Surprisingly, the ET group improved slightly more on the arm-curl test than the ST group. Although age did not differ significantly between the groups, a visual inspection of the data shows that the ST group was older than the ET group: 42% of participants in the ST group were 75 years or older. In a previous study we did not find significant difference between the training responses of young-old and older participants (Toraman and Şahin, 2004), although another study has reported that adults over 75 years of age had lower rates of restoration of function than participants in the 65–74 years age range (Beland and Zunzunegui, 1999).

The strength training protocol was adjusted by increasing resistance by 5% every two weeks and included a familiarization session in the previous week of training. Another possible reason for the small improvement in arm strength in the ST group is that the familiarization sessions before the study began might have caused motor learning–neural adaptations. Neural factors affect the maximal force output of a muscle by determining which and how many motor units generate force in a muscle contraction and the rate at which the motor units fire. Much of the improvement in strength in the first few weeks of resistance training is attributable to neural adaptations, as the brain learns how to generate more force from a given amount of contractile tissue (Harman, 2000). It is also possible that poor muscle and joint flexibility of the lower and upper extremities may have limited the extent of improvement in the arm-curl and chair-stand tests in the ST group. However, it is unclear how strength training affects the gains in strength in older people with a poor range of motion. Although we found no significant difference between the ST and ET groups, arm-curl performance was better at baseline in the ST group than in ET group. The ET group was taught the proper walking technique of keeping the elbows flexed firmly at a 90-degree angle, and swinging the arms from the shoulder so that the hands end their forward swing at the level of the sternum, and on the backswing end with the upper arm nearly parallel to the ground. Although aerobic exercise usually has little effect on muscular strength, this may have improved arm-curl performance in the ET group.

Latencies of the ERP components

There is evidence that aerobic exercise produces its effect on P3 by increasing arousal. Exercise helps to contribute to decreased peak latency (Polich and Lardon, 1997). Yagi et al. (1999) examined the auditory and visual P3 and reaction times in young volunteers before and after exercise on a cycle ergometer. They found that the facilitation of reaction times and P3 latency during exercise was accompanied by decreased accuracy on the oddball tasks. Bulut et al. (2003) reported that acute and regular exercise shortens the latency of sensory-evoked potentials.

We used ERP measurements to investigate the effects of the two exercise training modes on cognitive processing in older people. After nine weeks of training, the participants in the ET and ST groups had earlier N1 latencies, but unchanged P2, N2, and P3 latencies. However, the absolute decreases in the latencies of the P2 and N2 components at the Fz site and at the Cz site were greater in the ST group than in ET group. The absolute changes in the latencies of the N1, P2, and N2 components at the Fz site, and in the latencies of the P2 and N2 components at the Cz site were shorter in the ST group than in the C group. The changes in latencies of the P2 and N2 components at the Fz site and the N2 component at the Cz site were greater in the ET group than in the C group. Among the physiological factors involved in ERP variations, little attention has focused on the influence of exercise type. The P1, N1, P2 components of the ERP is attributed to early sensory processing (Emmerson-Hanover et al., 1994; Kayser et al., 2003; Pekkonen et al., 2005; Yagi et al., 1999; Yordanova et al., 2004). The role of exercise on selective VEP and BAEP components has been extensively studied in young and older participants (Delpont et al., 1991; Dustman et al., 1990) and in animal studies (Ozkaya et al., 2003). Shorter VEP and BAEP latencies and shorter reaction times have been reported in physically fit individuals compared with their sedentary peers (Chodzko-Zajko and Moore, 1994; Dustman et al., 1993; McDowell et al., 2003). In our previous study, we found that shortened VEP latencies after aerobic exercise were independent of changes in body temperature (Ozkaya et al., 2003). In our current study, recordings of the ERP components were made while the participants rested. Chmura et al. (1994) found that auditory and visual reaction times were immediately preceded by increases in the plasma concentrations of norepinephrine and epinephrine in exercising participants.

Amplitudes of ERP components

Although it is known that exercise helps to contribute to increased P300 amplitude (Polich and Lardon, 1997), McDowell et al. (2003) reported that the analysis of amplitude revealed no main effect for physical activity history.

The amplitudes of the ERP components corresponded with the latency values of the ERP components, except for the P3 latency and the N2P3 amplitude in the ST group. In the ST group, the amplitudes of the N1P2, P2N2, and N2P3 components at the Fz site and the N1P2 component at the Cz site increased, whereas these components did not change after training in the ET and C groups. The absolute changes in the amplitudes of the N1P2, P2N2, and N2P3 components at the Fz site and the N1P2 component at the Cz site were higher in the ST group than in the ET and C groups. These data suggest that participants in the ST group had shorter ERP latencies and superior N1P2 values at both sites. The higher N2P3 amplitude at both sites in the ST group compared with the ET and C groups suggests that strength training might improve cognitive function. Although greater amplitudes were observed in the ET group compared with the C group, these differences did not reach significance. To our knowledge, no study has investigated the effects of the different types of exercise training on cognitive function evaluated by ERP recordings.

The scalp distributions of the early ERP components P1, N1, and P2 were evidently modality specific, and within each modality, these early components were nearly identical for new and old items. These observations are consistent with other studies that used auditory (Wolpaw and Penry, 1975) and visual stimuli (Kayser et al., 1999). We presume that this pattern reflects the activation of different neural generators associated with an early, low-level analysis of auditory and visual stimuli (Kayser et al., 2003). The larger P1 and N1 amplitudes may reflect increased attention to external stimuli (Hillyard and Anllo-Vento, 1998). It is also possible that, when an older adult performs a more complex sensorimotor task, the motor responses need to be guided by, or executed with a stronger reference to, external stimuli, so that more attention is focused on these stimuli to support the movement excitation. If so, our data suggest that strength training may be a more complex sensorimotor task than endurance training.

In a recent study, Yordanova et al. (2004) found that functional dysregulation of motor cortex excitability during sensorimotor processing occurs with advanced age. In contrast, several cholinergic (Pekkonen et al., 2005) and non-cholinergic (Raudino et al., 1997; Tandon and Majahan, 1999) synaptic mechanisms are relevant to mediating the synaptic mechanisms involved in early sensory processing and cognition. In our study design, it is difficult to clarify by which synaptic mechanisms exercise might affect the sensorimotor cortex. However, our results suggest that strength training facilitates information processing.

Motor unit firing rates increase as a result of strength training in older individuals (Roth et al., 2000). In older individuals, strength training induces neurogenic adaptations, which contribute to improvements in muscular strength, although the specific neural adaptations resulting from strength training are often difficult to determine. To our knowledge, no study has investigated the effects of strength training on the CNS.

Extensive data show that aerobic exercise is associated with enhanced cognitive performance in older individuals (Dustman et al., 1990; Polich and Lardon, 1997). Two basic mechanisms have been suggested to explain the effect of aerobic fitness on cognitive processes: the cerebral circulation hypothesis and the neurotrophic-stimulation hypothesis, which predicts a beneficial effect of neuromuscular activity on higher brain centers; both mechanisms may contribute simultaneously (Dustman et al., 1993; Yagi et al., 1999). Our data showing shorter N1 latencies after training in both the ST and ET groups are consistent with these mechanisms.

However, we did not find any facilitating effect of moderate endurance training, which improved oxidative capacity in the ET group, on selective ERP components. One possible explanation is the higher aerobic capacity measured by the 6 min walk test in the ST group. The duration of the endurance training might have been inadequate for the slight change in oxidative capacity to contribute to improve cognition.

It is interesting that only small improvements in functional fitness affected cognitive performance. To our knowledge, no study has investigated the relation between the amount of the improvement in physical fitness and the amount of the improvement in cognitive function. It is likely that simple participation in group activities, which required sharing and following the instructors' orders, contributed to the improved cognitive function despite only small improvements in functional fitness. Chodzko-Zajko and Moore, (1994) conclude that the relationship between physical fitness and cognition is highly task dependent. Physical fitness effects are most likely to be observed with tasks that require rapid or effortful cognitive processing and are less likely to occur with automatic processing tasks (Chodzko-Zajko and Moore, 1994).

CONCLUSIONS

In conclusion, although there were no differences in functional fitness tests between the ST and ET groups, our results suggest that strength training may have facilitating effects on early information processing and cognition. The mechanism of the ERP changes induced by the strength training is not yet known. After strength training, neurobiological changes, such as changes in cerebral blood flow, neurotransmitter functioning, or increased cell complexity, might occur in different brain regions and contribute to CNS integrity. More research is needed to determine how the different exercise regimens contribute to discrete changes in CNS functioning and how such changes affect the P3 component of the ERP. These preliminary findings await replication using a larger sample size, which may provide a positive motivational force for the encouragement of multicomponent exercise programs that include aerobic, muscular strength, and flexibility components for older adults.

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REFERENCES

ACSM, American College of Sports Medicine (1995) *Guidelines for exercise testing and prescription.* 5th edition. Williams & Wilkins, Baltimore.

Beck, E.C. and Dustman, R.E. (1975). Changes in evoked responses during maturation and aging in man and macaque. In: *Behavior and Brain Electrical Activity*. Eds: Burch, N. and Altshuler, H.L. New York: Plenum Press, 431–472.

Beland, F. and Zunzunegui, M.V. (1999) Predictors of functional status in older people living at home. *Age Ageing* **28,** 153–159.

Brandon, L.J., Boyette, L.W., Gaasch, D.A. and Lloyd, A. (2000) Effects of lower extremity strength training on functional mobility in older adults. *Journal of Physical Activity and Aging* **8,** 214–227.

Bulut, S., Ozmerdivenli, R. and Bayer, H. (2003) Effects of exercise on somatosensory-evoked potentials. *International Journal of Neuroscience* **113,** 315–322.

Chmura, J., Mazar, K. and Kaciuba-Uscilko, H. (1994) Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. *International Journal of Sports Medicine* **15,** 172–176.

Chodzko-Zajko, W.J. and Moore, K.A. (1994) Physical fitness and cognitive functioning in aging. In: *Exercise and Sport Sciences Reviews.* Ed: Holloszy, J.O. Baltimore: Williams & Wilkins. 95–220.

Delpont, E., Dolisi, C., Suisse, G., Bodino, G. and Gastaud, M. (1991) Visual evoked potentials: Differences related to physical activity. *International Journal of Sports Medicine* **12,** 293–298.

Dice, J.F. (1993) Cellular and molecular mechanisms of aging. *Physiological Reviews* **73,** 149–159.

DiPietro, L. (1996) The epidemiology of physical activity and physical function in older people. *Medicine and Science in Sports and Exercise* **28,** 596–600.

Dustman, R.E., Shearer, D.E. and Emmerson, R.Y. (1993). EEG and event-related potentials in normal aging. *Progress in Neurobiology* **41,** 369–401.

Dustman, R.E., Emmerson, R.Y., Ruhling, R.O., Shearer, D.E., Steinhaus, L.A., Johnson, S.C., Bonekat, H.W. and Shigeoka, J.W. (1990) Age and fitness effects on EEG, ERPs, visual sensitivity, and cognition. *Neurobiology of Aging* **11,** 193–200.

Dustman, R.E., Ruhling, R.O., Russell, E.M., Shearer, D.E., Bonekat, H.W., Shigeoka, J.W., Wood, J.S. and Bradford, D.C. (1984) Aerobic exercise training and improved neurophysiological function of older individuals. *Neurobiology of Aging* **5,** 35–42.

Emmerson-Hanover, R., Shearer, D.E., Creel, D.J. and Dustman, R.E. (1994) Pattern reversal evoked potentials: gender differences and age-related changes in amplitude and latency. *Electroencephalography and Clinical Neurophysiology* **92,** 93–101.

Evans, W.J. and Cyr-Campbell, D. (1997) Nutrition, exercise, and healthy aging. *Journal of the American Dietetic Association* **97,** 632–638.

Feigenbaum, M.S. and Pollock, M.L. (1999) Prescription of resistance training for health and disease. *Medicine and Science in Sports and Exercise* **31,** 38–45.

Güngen, C., Ertan, E., Eker, E., Yaşar, R. and Engin, F. (1999) The SMMSE in Turkish. *International Psychogeriatrics* **11** (Suppl. 1), 78.

Harman, E. (2000) The biomechanics of resistance exercise. In: *Essentials of Strength Training and Conditioning*. Eds: Baechle, T.R. and Earle, R.W. Champaign, IL.: Human Kinetics. 25-56.

Hass, C.J., Feigenbaum, M.S. and Franklin, B.A. (2001) Prescription of resistance training for healthy populations. *Sports Medicine* **31,** 953–964.

Hatta, A., Nishihira, Y., Kim, S.R., Kaneda, T., Kida, T., Kamijo, K., Sasahara, M. and Haga, S. (2005) Effects of habitual moderate exercise on response processing and cognitive processing in older adults. *Japanese Journal of Physiology* **55,** 29–36.

Heinze, H.J., Münte, T.F., Kutas, M., Butler, S.R., Naatanen, R., Nuwer, M.R. and Goodin, D.S. (1999) Cognitive event related potentials. The International Federation of Clinical Neurophysiology. *Electroencephalography and Clinical Neurophysiology (Supplement)* **52,** 91–97.

Hillyard, S.A. and Anllo-Vento, L. (1998) Event related brain potentials in the study of visual selective attention. *Proceedings of the National Academy of Science USA* **95,** 781–787.

Kasch, F.W., Boyer, J.L., Schmidt, P.K., Wells, R.H., Wallace, J.P., Verity, L.S. Guy, H. and Schneider, D. (1999) Ageing of the cardiovascular system during 33 years of aerobic exercise. *Age Ageing* **28,** 531–536.

Kayser, J., Bruder, G.E., Friedman, D., Tenke, C.E., Amador, X.F., Clark, S.C., Malaspina, D. and Gorman, J.M. (1999) Brain event-related potentials (ERPs) in schizophrenia during a work recognition memory task. *International Journal of Psychophysiology* **34**, 249–265.

Kayser, J., Fong, R., Tenke, C.E. and Bruder, G.E. (2003) Event-related brain potentials during auditory and visual word-recognition memory tasks. *Cognitive Brain Research* **16**, 11–25.

Kügler, C.F.A., Taghavy, A. and Platt, D. (1993) The event-related P300 potential analysis of cognitive human brain aging: a review. *Gerontology* **39,** 280–303.

McDowell, K., Kerick, S.E., Santa Maria, D.L. and

Hatfield, B.D. (2003) Aging, physical activity, and cognitive processing: an examination of P300. *Neurobiology of Aging* **24,** 597–606.

Ozgocmen, T., Ozgocmen, S., Yoldas, T., Kamanli, A., Yildizhan, H., Yigiter, R. and Ardicoglu, O. (2003) Auditory P300 event related potentials and serotonin reuptake inhibitor treatment in patients with fibromyalgia. *Annals of the Rheumatic Diseases* **62,** 551–555.

Ozkaya, Y.G., Agar, A., Hacioglu, G., Yargicoglu, P., Abidin, I. and Senturk, U.K. (2003) Training-induced alterations are not related to body temperature. *International Journal of Sports Medicine* **24,** 359–362.

Pekkonen, E., Jaaskelainen, I.P., Kaakkola, S. and Ahveninen, J. (2005) Cholinergic modulation of preattentive auditory processing in aging. *Neuroimage* **23** (in press)

Picton, T.W., Stapells, D.R., Perrault, N., Baribeau-Braun, J. and Stuss, D.T. (1984) Human event-related potentials: Current perspectives. In: *Evoked potentials II,* Eds: Nodar, R.H. and Barber, C. Boston: Butterworth. 3–16.

Polich, J. (2004) Clinical application of the P300 event-related brain potential. *Physical Medicine and Rehabilitation Clinics of North America* **15,** 133–161.

Polich, J. and Lardon, M.T. (1997) P300 and long-term physical exercise. *Electroencephalography and Clinical Neurophysiology* **103,** 493–498.

Pollock, M.L., Franklin, B.A., Balady, G.J., Chaitman, B.L., Fleg, J.L., Fletcher, B., Limacher, M., Piña, I.L., Stein, R.A., Williams, M. and Bazzarre, T. (2000) AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: Benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association: Position paper endorsed by the American College of Sports Medicine. *Circulation* **101,** 828–833.

Raudino, F., Garavaglia, P., Beretta, S. and Pellegrini, G. (1997) Auditory event-related potentials in Parkinson's disease. *Electromyography and Clinical Neurophysiology* **37,** 409–413.

Regan, D. (1972) *Evoked potentials in psychology and clinical medicine*. Chapman and Hall, London.

Rikli, R.E. and Jones, C.J. (1998) The reliability and validity of a 6-minute walk test as a measure of physical endurance in older adults. *Journal of Aging and Physical Activity* **6,** 363–375.

Rikli, R.E. and Jones, C.J. (1999a) Developmental and validation of a functional fitness test for community-residing older adults. *Journal of Physical Activity and Aging* **7,** 129–161.

Rikli, R.E. and Jones, C.J. (1999b) Functional fitness normative scores for community-residing older adults, aged 60–94. *Journal of Physical Activity and Aging* **7,** 162–181.

Rikli, R.E. and Jones, C.J. (2001) *Senior fitness test manual*. Human Kinetics, Champaign, IL.

Rogers, M.E., Rogers, N.L., Takeshima, N. and Islam, M.M. (2003) Methods to assess and improve the physical parameters associated with fall risk in older adults. *Preventive Medicine* **36,** 255–264.

Roth, S.M., Ferrell, R.E. and Hurley, B.F. (2000) Strength training for the prevention and treatment of sarcopenia. *The Journal of Nutrition, Health and Aging* **4,** 143–155.

Tandon, O.P. and Majahan, A.S. (1999) Averaged evoked potentials: event-related potentials [ERPs] and their applications. *Indian Journal of Physiology and Pharmacology* **43,** 425–434.

Toraman, F. and Şahin, G. (2004) Age responses to multicomponent training programme in older adults. *Disability and Rehabilitation* **26,** 448–454.

Van Boxtel, M.P., Paas, F.G., Houx, P.J., Adam, J.J., Teeken, J.C. and Jolles, J. (1997) Aerobic capacity and cognitive performance in a cross-sectional study. *Medicine and Science in Sports and Exercise* **29,** 1357–1365.

Wilmore, J.H. and Costill, D.L. (1994) *Physiology of sport and exercise*. Human Kinetics, Champaign, IL.

Wolpaw, J.R. and Penry, J.K. (1975) A temporal component of the auditory evoked response. *Electroencephalography and Clinical Neurophysiology* **39**, 609—620.

Yagi, Y., Coburn, K.L., Estes, K.M. and Arruda, J.E. (1999) Effects of aerobic exercise and gender on visual and auditory P300, reaction time, and accuracy. *European Journal of Applied Physiology* **80,** 402–408.

Yamaguchi, S. and Knight, R.T. (1991) Age effects on the P300 to novel somatosensory stimuli. *Electroencephalography and Clinical Neurophysiology* **78,** 297–301.

Yesevage, J.A., Brink, T.L., Rose, T.L., Lum, O., Huang, V., Adey, M. and Leirer, O. (1983) Development and validation of a geriatric depression screening scale:a preliminary report. *Journal of Psychiatric Research* **17,** 37–49.

Yordanova, J., Kolev, V., Hohnsbein, J. and Falkenstein, M. (2004) Sensorimotor slowing with ageing is mediated by a functional dysregulation of motor-generation processes: Evidence from high-resolution event-related potentials. *Brain* **127,** 351–362.

Yu, B.P. (1994) Cellular defenses against damage from reactive oxygen species. *Physiological Reviews* **74,** 139–162.

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Employment

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KEY POINTS

- Strength training may have facilitating effects on early information processing and cognition in older people.
- It is interesting that only small improvements in functional fitness affected cognitive performance.
- More research is needed to determine how the different exercise regimens contribute to discrete changes in CNS functioning and how such changes affect the P3 component of the ERP.

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