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Do Younger and Older Adults Experience Similar Adaptations to Individualized Exercise Training?

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ABSTRACT

Elyza E. Montano, Jamie M. Keith, Christina A. Buchanan, Lance C. Dalleck. Do Younger and Older Adults Experience Similar Adaptations to Individualized Exercise Training? **JEPonline** 2018;21 (6):41-59. The purpose of this study was two-fold: (a) to identify whether or not younger individuals experience greater training adaptations when compared to their older counterparts in relation to cardiorespiratory fitness, muscular fitness, body composition, and flexibility; and (b) to identify whether or not younger individuals have more pronounced improvements in their cardiometabolic risk factor profile faster with individualized exercise training than older counterparts. Physically inactive men and women between the ages of 18 to 35 (n=10) and 50 to 70 (n=8) participated in an 8-wk exercise program separated into two phases: Phase 1 (weeks 1-4) at $HR < VT1$ and Phase 2 (weeks 5-8) at $HR \geq VT1 < VT2$. There were significant differences in all fitness measures (cardiorespiratory fitness, muscular fitness, body composition, and flexibility) from baseline to post-program in the younger group ($P<0.05$). Similarly, there were significant differences found for all fitness measures except leg press 5-RM and sit-and-reach from baseline to post-program in the older group ($P<0.05$). Furthermore, there was a significant reduction from baseline to post-program systolic blood pressure ($P<0.05$) in the older group alone. Cardiometabolic risk factor profiles generally improved in both age groups, although were not significant. The findings indicate that the older individuals were able to improve their fitness levels to the same relative extent as younger individuals with an individualized exercise prescription.

Key Words: Aging, Cardiorespiratory Fitness, Individualized Exercise Prescription, Muscular Fitness

INTRODUCTION

It is well known that fitness levels decline with age due to physiological and behavioral factors (13). The physiological factors that impact the decline in fitness include changes within the structure and function of the heart, lungs, and muscle fibers (17,24). Behavioral factors associated with a decline in fitness include physical inactivity or sedentary living, poor diet, tobacco use, and alcohol consumption. Physical fitness refers to a state of health and well-being and the individual's ability to perform a variety of physical activities within the realm of sports, occupations, and activities of daily living.

The health-related components of physical fitness include cardiorespiratory fitness, muscular fitness, body composition, and flexibility. These components are important determinants of several health outcomes. It is widely accepted that regular physical activity and exercise assist in improving the health-related components of fitness (10,23). However, the aging process reduces maximal oxygen consumption (VO_2 max), muscle strength and mass, and flexibility, while increasing total body mass and fat mass (30).

To improve the decline of physical fitness components with age, publications by the American College of Sport Medicine (1), in conjunction with the U.S. Centers for Disease Control and Prevention (CDC), the U.S. Surgeon General, and the National Institutes of Health have sought to set recommendations for adults to be physically active (1). Physical activity is defined as body movement that is produced by the contraction of skeletal muscles and that increases energy expenditure. Evidence in the literature supports the use of physical activity to reduce the risk of chronic disease, cardiovascular disease, hypertension, stroke, osteoporosis, type 2 diabetes mellitus, metabolic syndrome, cancer, and premature mortality among a wide range of ages that will improve overall physical fitness (3). The leading cause of approximately 48% of deaths in the United States is attributed to cardiovascular disease and cancer (13).

Research also suggests that physical activity declines as early as adolescence (6) with approximately 22.4% of 18 to 24 yrs of age reporting no physical activity (26) and between 57 to 61% of college students reporting no moderate to vigorous exercise for 3 days within the last 7 days (6). In addition, only 34% of young individuals within a population of 203 men and women had no cardiovascular risk factors (26). Physical activity can lower the risk of various health conditions and can also improve the health components of physical fitness. Therefore, the recommendation among all adults is to avoid physical inactivity (1,7).

Advanced aging reduces the health-related components of fitness. The decline in VO_2 max that occurs with aging has varied widely among the findings in the literature, ranging from 0 to 34% per decade (2,25). This decline in VO_2 max is linked to an increase in the risk of cardiovascular disease. Low cardiorespiratory fitness is associated with cardiovascular disease and all-cause mortality (16,21). The importance of increasing cardiorespiratory fitness is to decrease the likelihood of death from all natural causes (1) and favorably change blood pressure (BP), metabolic profile, body composition, and other cardiovascular disease risk factors (16). Another health implication associated with the decline in VO_2 max is loss of the ability to perform activities of daily living, leading to decreased independence among older individuals (2).

The decline in cardiorespiratory fitness is not the only decline seen with the aging process. Muscular strength decreases approximately 30 to 50% between the ages of 30 and 80 yrs in both men and women with much of the loss being after the age of 50 and menopause (8,25). The most pronounced decrease is approximately 12 to 14% per decade after age 50. The decline in muscular strength is a strong predictor of disability in old age as well as mortality risk (7).

There is also a 2 to 3% decline in fat free mass per decade from 30 to 70 yrs of age (7). Within sedentary individuals, 8 to 9 kg are gained between the ages of 18 and 55, mostly attributed to fat gain (7). The implications of unfavorable changes in body composition are increased risk of cardiovascular and metabolic disease, obesity, and insulin resistance (27). The consensus for flexibility is that joint range of motion (ROM) declines significantly by age 70 for hip, spine, and ankle, especially in women. The implications of low flexibility and joint ROM include an increased risk of injury, falling, stiffness in joints, and back pain (7). These changes occur with advancing age; however, they can be delayed with physical activity (7).

The knowledge recognized about the decline in physical fitness components with aging causes ambiguity with regard to whether older individuals adapt to training similarly to their younger counterparts. Studies have shown improvements in both older and younger individuals when comparing VO_2 max, body composition, lipid profiles, and muscular strength from baseline to post-testing. However, research has not quantified the magnitude of the change over time while focusing on the differences in change between ages.

Thus, the purpose of this study was to determine if younger and older individuals have comparable fitness and cardiometabolic related adaptations to individualized exercise training.

METHODS

Subjects

Twenty-six sedentary, low-to-moderate risk men and women 18 to 35 and 50 to 65 yrs of age provided informed consent to participate in this study. The subjects' characteristics are presented in Table 1. The study was explained in detail to the subjects prior to data collection. Recruitment of the subjects occurred in response to the Western State Colorado University Information email system, posters, and word-of-mouth. The subjects were individuals who did not meet the ACSM criteria for physical activity (30 $\text{min}\cdot\text{d}^{-1}$ of moderate exercise for ≥3 $\text{d}\cdot\text{wk}^{-1}$). All women in the older age group were post-menopausal. A medical history questionnaire and physical activity readiness questionnaire (PAR-Q) were filled out to screen for risk factors and to ensure safety of physical activity.

Subjects were excluded from the study if they were categorized as high risk according to the ACSM guidelines, pregnant or may be pregnant, injured or disabled, or exceeded the physical activity guidelines. Data were collected in the High Altitude Performance Laboratory and Fitness Center in the Mountaineer Field House at Western State Colorado University. This study was approved (HRC2017-02003R30) by the Human Research Committee at Western State Colorado University.

Table 1. Subject Characteristics at Baseline.

Variable	Younger (n=10)	Older (n=8)
Age (yrs)	28.2 ± 4.3	57.1 ± 6.3
Body Mass Index ($kg \cdot m^{-2}$)	26.9 ± 5.6	27.3 ± 3.1
Height (cm)	168.7 ± 9.8	171.9 ± 8.6
Weight (kg)	77.3 ± 22.2	80.7 ± 10.0

Experimental Design

The subjects were asked to attend four sessions for baseline testing. The first session was to obtain informed consent and to familiarize the subjects with the program commitment. In this session, the subjects also took a quality of life survey. After obtaining informed consent, the subjects went to the laboratory early one morning for the second session to measure fasting blood lipid profiles, BP, and resting heart rate (HR). The third session of baseline testing included a VO_2 max test, skinfold test, flexibility test, and other measurements including height, weight, and waist circumference. The fourth session occurred after access to the gym was obtained. This session consisted of 5-RM testing for leg press and bench press to measure muscular strength.

Following baseline testing, an individualized 8-wk exercise program according to ACE Integrated Fitness Training Model guidelines was developed for each subject by the researchers. Phase 1 consisted of weeks 1-4 with the subjects exercising 3-4 $d \cdot wk^{-1}$ for 45 to 60 $min \cdot wk^{-1}$. Phase 2 consisted of weeks 5-8 with the subjects exercising 5 $d \cdot wk^{-1}$ for 60 to 75 $min \cdot d^{-1}$.

The subjects performed specific functional, resistance, and cardiorespiratory exercises recommended for each phase as outlined in Chapters 9 to 11 of the ACE Personal Trainer Manual (5). Following the intervention, post-program measurements were assessed, including all the measurements taken at baseline. Refer to Figure 1 for the experimental flow chart of the study design.

Procedures

Outcome variables were assessed at baseline (week 1) and post-program (week 10) among all the subjects. Measurements were obtained by standardized procedures and described in the following sections.

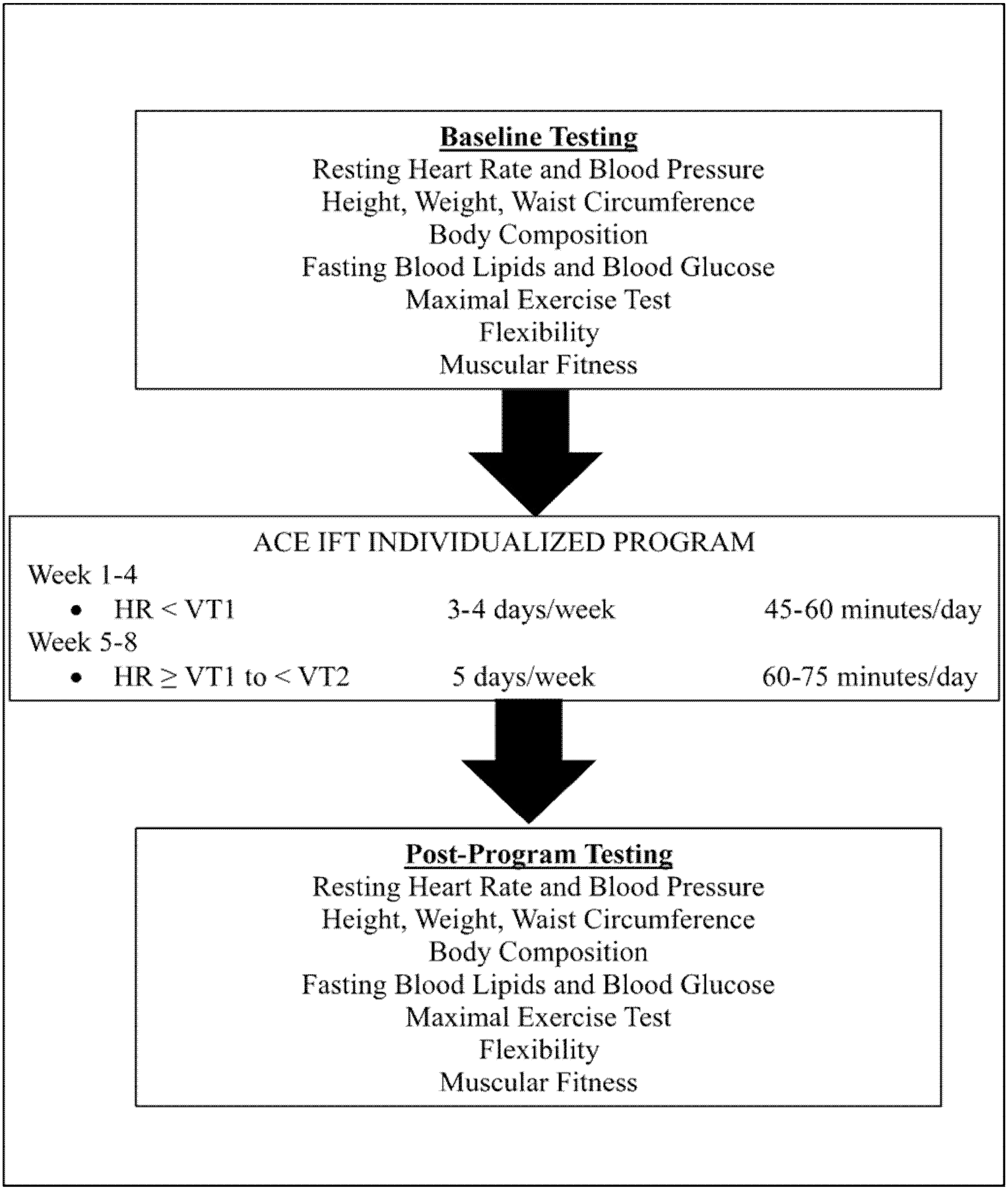

Figure 1. Experimental Flow Chart.

Resting Heart Rate and Blood Pressure Measurement

Resting HR was measured by a HR monitor (Polar Electro Company, Kempele, Finland) after the subject rested for 5 to 10 min in a chair. For resting BP, subjects were seated quietly in a chair with feet on the ground and left arm supported at heart level. Blood pressure was taken manually. The left arm brachial artery BP was taken with the use of a sphygmomanometer and stethoscope (American Diagnostic Corp., Hauppauge, NY). The sphygmomanometer was placed snugly above the brachial artery. The stethoscope was placed over the brachial artery near the crease of the arm. The cuff bulb was then inflated to about 180 to 200 mmHg. It was released at approximately 2 to 3 mmHg per second for accuracy. The first rhythmic sound heard was the systolic pressure and the last fading rhythmic sound was the diastolic pressure. Duplicate measurements were taken for consistency, separated by a couple of minutes, and averaged provided the measures were within 4 to 6 mmHg.

VO_2 Max Test

The subjects performed a modified Balke, graded exercise test (GXT) on a treadmill. A HR monitor (Polar Electro Co., Kempele, Finland) was attached via chest strap to each subject throughout the warm-up and GXT. The modified Borg's scale was used as a subjective measure to obtain rate of perceived exertion (RPE). This scale of 1 to 10 was explained to subjects prior to the start of the test along with other instructions. The subjects had a 2 to 3 min warm-up at a self-selected pace. Then the subject was instructed to put a mask on (KORR Medical Technologies Inc., Salt Lake City, UT) to collect expired air and gas exchange data with a metabolic analyzer (Parvomedics Inc., Sandy, UT). The GXT started at a self-selected pace, which remained constant throughout the test. Subjects were instructed to use hand signals at the end of each minute for rate of perceived exertion (RPE) measurements, along with HR readings at each minute. Treadmill incline increased by 1% every minute until the subject reached volitional fatigue. Termination of the test was determined by any of the following: (a) the subject's inability to continue; (b) chest pain; (c) shortness of breath; (d) wheezing; or (e) any other condition limiting the subject to continue. The criteria for VO_2 max testing consisted of identifying two of the following: (a) a plateau in VO_2 at VO_2 max; (b) RPE of 9 or 10; (c) a maximal HR within 15 $\text{beats}\cdot\text{min}^{-1}$ of age predicted maximal HR; and (d) respiratory exchange ratio equal to or greater than 1.1.

Skinfold Test

All skinfold measurements were taken using the three-site assessment in both males and females. Males were assessed based on the chest, abdomen, and thigh. Females were assessed based on triceps, suprailiac, and thigh. All measurements were made on the right side of the body with the subject standing upright. The device used was a skinfold caliper (Health Check Systems Inc., Brooklyn, NY) that was placed directly on the skin surface. The subjects were pinched momentarily while the researchers read the caliper. Duplicate measurements at each site were taken to ensure consistency and retested if measurements were not within 1 to 2 mm (1). The three-site formula (chest, abdomen, and thigh) for men to calculate body density = 1.10938-0.0008267 (sum of three skinfolds) + 0.0000016 (sum of three skinfolds)^2 -0.000244 (age). The three-site formula (triceps, suprailiac, and thigh) for women to calculate body density = 1.099421- 0.0009929 (sum of three skinfolds) + 0.0000023 (sum of three skinfolds)^2 -0.0000979 (age). Once body density was determined, body fat was calculated by the equation,

$$\%\ \text{fat} = \frac{457}{body\ density} - 414.2$$

Blood Lipid and Glucose Profile Test

Fasting blood lipids and fasting blood glucose (FBG) were analyzed using the Cholestech LDX System (Alere Inc., Waltham, MA). The subjects were instructed to refrain from all food and drinks with the exception of water for 12 hrs. On the day of testing, the subjects were asked to wash their hands with soap and rinse thoroughly with water. A finger was prepared by cleansing it with an alcohol swab and allowed to air-dry for 20 sec. The skin was punctured with a lancet from which the first drop of blood was wiped away with gauze. A fingerstick sample was collected into a heparin-coated 40 microliter capillary tube. Samples were then dispensed immediately onto the lipid cassette (Stat Technologies Inc., Golden Valley, MN) for analysis using the Cholestech LDX System. All materials were disposed of properly in biohazard containers. The Cholestech LDX System measured total cholesterol (TC), triglycerides (TRG), high-density lipoproteins (HDL), low-density lipoproteins (LDL), and fasting blood glucose (FBG).

Flexibility Test

The subjects performed a sit-and-reach test with a sit-and-reach box (Novel Products Inc., Rockton, IL). They were instructed to sit against a wall with shoulder blades touching the wall and soles of the feet touching the sit and reach box. The subjects performed the test with shoes. To adequately assess flexibility, the box was adjusted accordingly, and subjects were instructed to only bend at the hip while keeping shoulder blades back. Measurements were taken in centimeters.

Muscular Fitness and Functional Measurements

Assessment protocols of muscular fitness and functional measurements are described in another research study (10). Static balance was assessed via the stork-stand balance test. Subjects followed instructions to raise one foot off the ground and lightly touch the stance leg below the knee without moving the stance leg or making contact with the ground with the elevated leg. As for muscular fitness, the subjects performed five-repetition maximum (5-RM) testing for bench press and leg press exercises.

ACE Integrated Fitness Training Model

Individualized exercise training was designed according to the ACE Integrated Fitness Training model (5). Target HR for each phase was established such that weeks 1 to 4 consisted of HR < VT1 and wks 5 to 8 consisted of HR ≥ VT1 to <VT2. The determination of the first and second ventilatory threshold was made by observation of V_E/VO_2 and V_E/VCO_2 plotted graphs of VT1 and VT2, respectively. Assessment was carried out by the primary investigator and an experienced exercise physiologist.

The breakdown of each week is shown in Figure 2. Subjects were instructed to wear a HR monitor during all exercise sessions. Workloads were adjusted to meet target HR guidelines on all aerobic modalities. The subjects were able to choose from the indoor track, treadmill, recumbent bike, upright bike, elliptical, stair stepper, and rower. Resistance training was incorporated into the prescribed program during week 3. Subjects were monitored for safety, technique, and progression. The specific details for the ACE IFT prescription of resistance training are outlined elsewhere (10). The muscles targeted were hamstrings, glutes, quadriceps, triceps, shoulders, chest, and back.

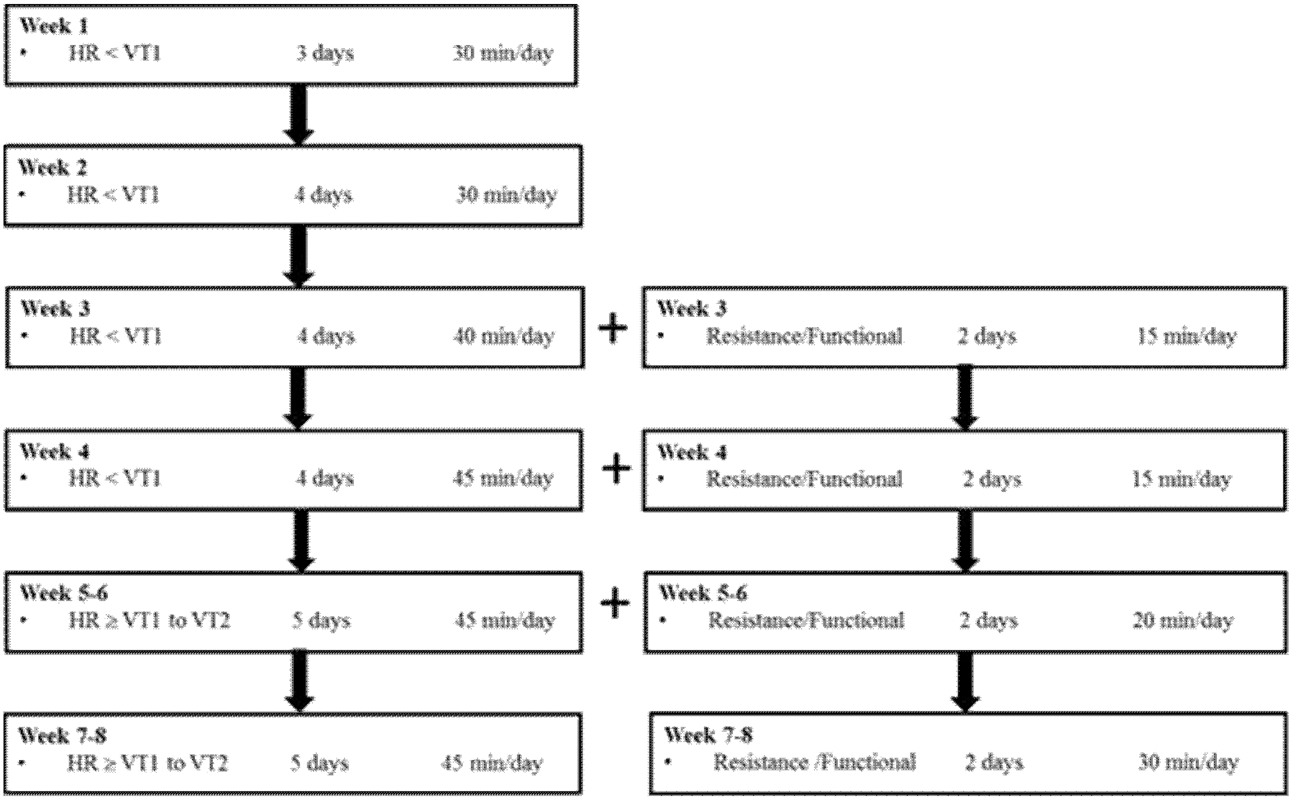

Figure 2. Week-to-Week Exercise Prescription for Days/Times of Aerobic and Resistance Training.

Statistical Analyses

All analyses were performed using the SPSS Version 24.0 (Chicago, IL, USA). Statistical significance was set to $P<0.05$. Paired *t*-tests were used to determine the mean differences in primary and secondary outcomes within groups between baseline and post-program testing. Independent *t*-tests were performed to compare the baseline to post-program changes between the young and old groups. The repeated measures analysis of variance (ANOVA) was used to determine differences in the change in primary and secondary outcomes from baseline to post-program across experimental groups.

RESULTS

All analyses and data presented in the results are for the subjects who completed the study. Of the subjects who began the program, there were 6 younger subjects and 2 older subjects who dropped out due to either illness (n=3), injury outside of the program (n=3), or personal matters (n=2). After reviewing the exercise-training logs, the adherence of the program for younger subjects was approximately 91%; whereas, for older individuals it was 95%. Subjects in both groups adhered well to the HR thresholds as shown in Figure 3.

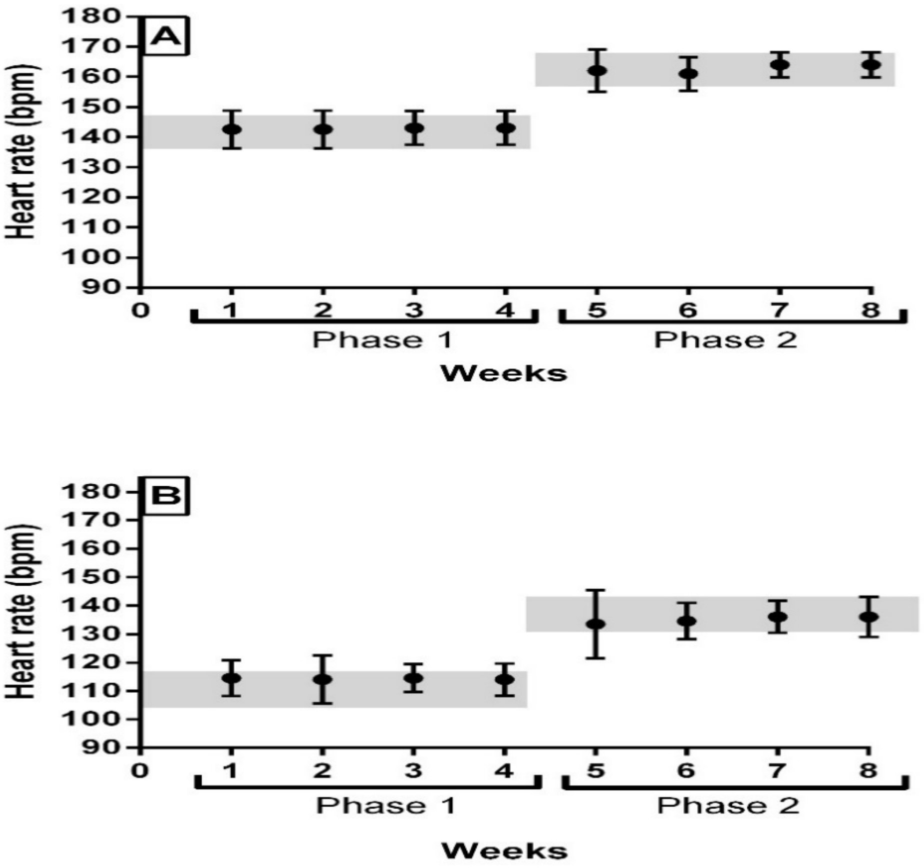

Figure 3. Exercise Adherence. Graph 3A Depicts the Actual HR Ranges for Each Week Relative to the Threshold HR (Shaded Area) Prescribed Among Younger Individuals. Graph 3B Depicts the Same as Graph 3A But for Older Individuals.

Health-Related Fitness Measurements

The health-related fitness measurements at baseline and post-program for younger and older subjects are presented in Table 2. Paired *t*-tests were conducted to examine the effect of the individualized 8-wk exercise program from baseline to post-program on fitness measures that included VO_2 max, bench press 5-RM, leg press 5-RM, body composition, and sit-and-reach. There were significant differences ($P<0.05$) in all variables for the younger group [t(9) = -2.50, t(8) = -2.80, t(8) = -5.82, t(9) = 3.69, and t(9) = 6.42, respectively].

In the older group, there were significant differences ($P<0.05$) for VO_2 max, bench press 5-RM, and body composition [t(7) = -2.76, -3.67, and 7.19, respectively]. There were no significant differences ($P>0.05$) for leg press 5-RM and sit-and-reach within the older group.

Independent *t*-tests were conducted to examine if a difference existed between younger and older groups in the changes from baseline to post-program in VO_2 max, bench press 5-RM, leg press 5-RM, body composition, and sit-and-reach. There were no significant differences ($P>0.05$).

Table 2. Health-Related Fitness Measurements at Baseline and Post-Program.

	Younger (n=10)		**Older** (n=8)	
Variable	**Baseline**	**Post**	**Baseline**	**Post**
VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)	30.4 ± 9.7	33.2 ± 7.8*	25.6 ± 6.2	28.6 ± 6.2*
Bench Press (kg)	33.0 ± 20.1	37.4 ± 18.4*	37.4 ± 14.7	40.5 ± 15.6*
Leg Press (kg)	111.3 ± 75.4	153.1 ± 71.5*	90.7 ± 45.5	111.9 ± 76.
Body Composition (%)	26.6 ± 4.7	21.8 ± 3.8*	25.1 ± 5.7	19.2 ± 5.0*
Sit-and-Reach (cm)	24.6 ± 7.9	31.2 ± 6.7*	21.3 ± 5.6	24.9 ± 5.0

*Statistically significant, P<0.05

Cardiometabolic Risk Factor Profile

The cardiometabolic risk factor profiles at baseline and post-program for younger and older individuals are presented in Table 3. Paired *t*-tests were conducted to examine the effect of an individualized 8-wk program from baseline to post-program on cardiometabolic risk factors including LDL-Chol, HDL-Chol, TC, TRG, and FBG. There were no significant differences for any variables in the younger group. There was a significant decrease in systolic BP in the older group [t (7) = 5.12, P=.001]. An independent *t*-test was conducted to determine if there was a difference in cardiometabolic risk factor profiles between younger and older groups. Total cholesterol was improved more by the older subjects compared to the younger subjects. Otherwise, there were no significant differences (P>0.05) between the groups for all other variables.

Table 3. Cardiometabolic Risk Factor Profile at Baseline and Post-Program,

	Younger (n=10)		**Older** (n=8)	
Variable	**Baseline**	**Post**	**Baseline**	**Post**
FBG ($mg \cdot dL^{-1}$)	87.9 ± 9.0	87.4 ± 8.6	99.3 ± 12.4	97.4 ± 11.3
HDL-Chol ($mg \cdot dL^{-1}$)	39.2 ± 10.5	49.7 ± 17.7	52.9 ± 13.6	53.4 ± 13.0
LDL-Chol ($mg \cdot dL^{-1}$)	116.0 ± 39.7	126.0 ± 28.2	136.3 ± 51.5	125.6 ± 51.5
TC ($mg \cdot dL^{-1}$)	179.3 ± 39.8	194.1 ± 32.7	214.9 ± 51.5	195.5 ± 43.4
TRG ($mg \cdot dL^{-1}$)	153.7 ± 88.0	137.7 ± 49.0	144.9 ± 38.2	114.7 ± 36.7
Systolic BP (mmHg)	113.3 ± 8.7	109.2 ± 6.6	116.5 ± 8.1	110.3 ± 5.4*
Diastolic BP (mmHg)	71.4 ± 9.1	71.4 ± 7.0	77.9 ± 8.1	67.3 ± 9.5

*Statistically significant, P<0.05; **BP** = Blood Pressure; **FBG** = Fasting Blood Glucose; **HDL-Chol** = High-Density Lipoprotein Cholesterol; **LDL-Chol** = Low-Density Lipoprotein Cholesterol; **TC** = Total Cholesterol, **TRG** =Triglycerides

Anthropometric Measures and Resting Heart Rate

Anthropometric measures at baseline and post-program for the younger and older subjects are presented in Table 5. Paired *t*-tests were conducted to examine the effect of the individualized 8-wk program from baseline to post-program on anthropometric measures including weight, waist circumference, and resting HR. There were no significant (P>0.05) improvements for any of the variables in either group.

Table 4. Anthropometric Measures and Resting Heart Rate at Baseline and Post-Program.

	Younger (n=10)		**Older** (n=8)	
Variable	**Baseline**	**Post**	**Baseline**	**Post**
Resting Heart Rate (beats·min^{-1})	68.3 ± 10.2	68.0 ± 10.9	72.1 ± 8.0	67.3 ± 9.5
Waist Circumference (cm)	81.5 ± 14.5	81.0 ± 13.5	90.1 ± 8.3	90.2 ± 8.5
Weight (kg)	77.3 ± 22.2	77.1 ± 21.4	80.7 ± 10.0	80.0 ± 10.4

*Statistically significant, P<0.05

Incidence of Responders

Delta values (Δ) were calculated (post-program minus baseline value) for change in VO_2 max, leg press 5-RM, bench press 5-RM, body composition, sit-and-reach, FBG, HDL-Chol, LDL-Chol, TC, TRG, systolic BP, diastolic BP, WC, weight, and HR. The subjects were categorized as '1' = responder (change in the favorable direction) or '0' = non-responder (no change or undesirable change).

Pearson's Chi squared tests were used to stratify the responsiveness to fitness measures, cardiometabolic risk factors and anthropometric measures between the younger and older groups. When examining the prevalence of training responsiveness according to age using χ2 difference testing, there were no significant differences (P>0.05) for all outcomes measures (Figure 4).

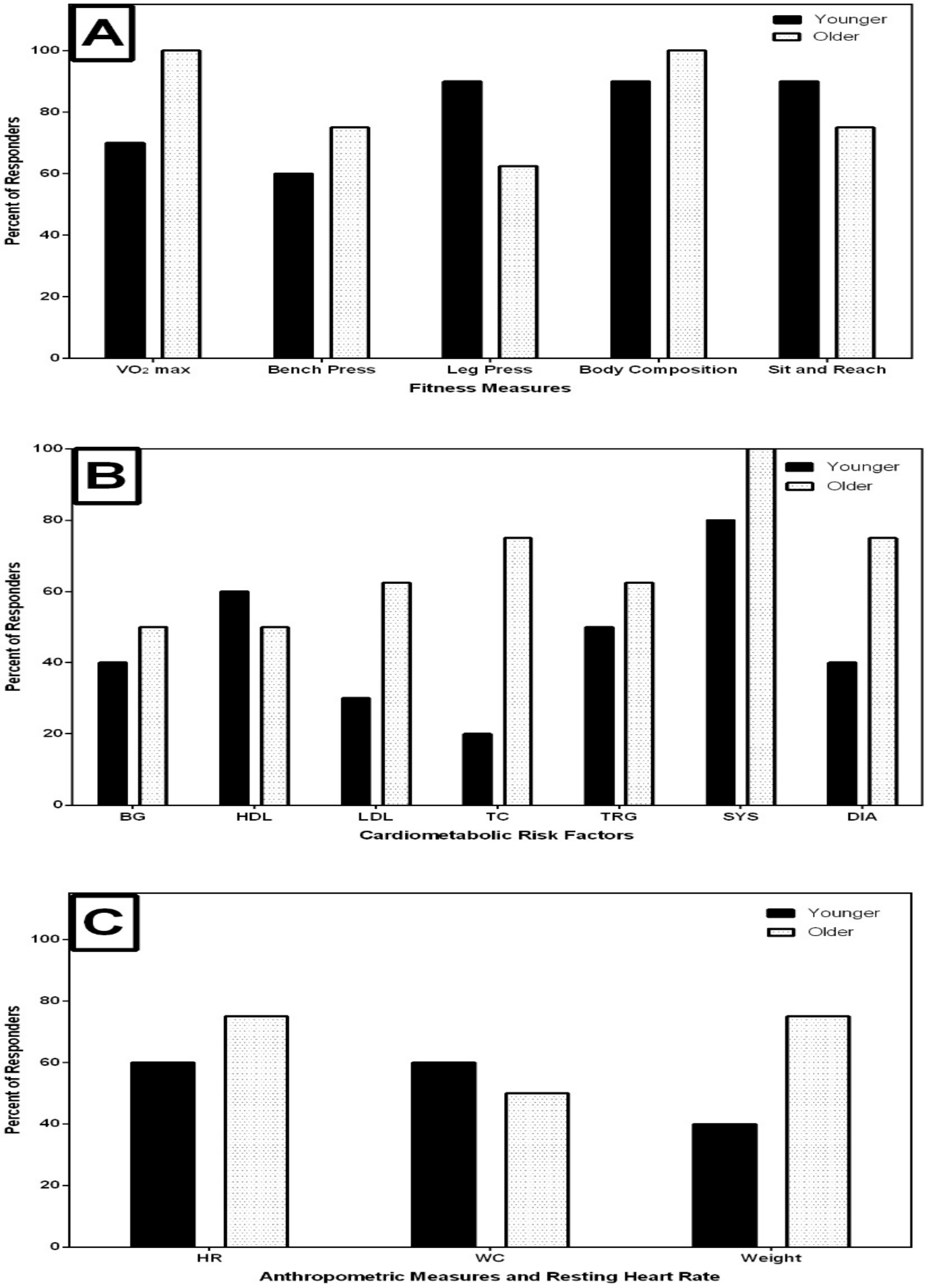

Figure 4. Incidence of Responders to Health-Related Fitness Measurements, Cardiometabolic Risk Factors, Anthropometric Variables, and Resting Heart Rate.

DISCUSSION

The primary, novel finding from the present study was that an individualized exercise prescription positively modified health-related fitness measurements to a similar extent in both the younger and the older subjects. The personalized approach of the ACE IFT Model utilizes ventilatory threshold in prescribing exercise; whereas, other studies may use the percent approach. Indeed, in most of the literature, the prescribed exercise intensity has been based on a percentage of HR max, VO_2 max, VO_2R, or HRR with the idea of one size fits all (32). There is a wide range of variability within these prescribed intensities such that it may be challenging to elicit the desired metabolic responses resulting in some individuals exercising either above or below their individual metabolic threshold (32). Therefore, individualizing the exercise intensity method and program is beneficial in eliciting the metabolic responses necessary to see favorable adaptations in the measurements of health-related fitness (10,35).

Health-Related Fitness Measurements

Cardiorespiratory Fitness

Both groups showed improvements in all measurements of fitness although some were not statistically significant. The current research study found a mean increase in VO_2 max of 2.8 $mL \cdot kg^{-1} \cdot min^{-1}$ or 9.3% in the younger subjects and a mean increase of 3.1 $mL \cdot kg^{-1} \cdot min^{-1}$ or 11.9% in the older subjects. In a study conducted by Willoughby et al. (34), younger (20 to 30 yrs) and middle-aged (40 to 50 yrs) individuals were assessed over 4 wks of sprint interval training. They reported an improvement of 1.5 $mL \cdot kg^{-1} \cdot min^{-1}$ or 3.9% in the younger group and 1.8 $mL \cdot kg^{-1} \cdot min^{-1}$ or 5.2% in the middle-aged group. This suggests that a shorter duration and higher intensity training intervention is beneficial in the improvement of fitness in a similar way between younger and older individuals.

Kohrt et al. (20) found an increase in VO_2 max over a 9 to 12-month period that exhibited an improvement of 9 to 14% in older individuals (61 to 70 yrs). A more recent study replicated these results in older individuals showing an increase of 5 $mL \cdot kg^{-1} \cdot min^{-1}$ or a 19% improvement over a yearlong intervention of progressive and vigorous-intensity exercise training (11). Similarly, a 2-yr supervised high intensity training study found an increase of 5.3 $mL \cdot kg^{-1} \cdot min^{-1}$ or an 18% improvement in VO_2 max (14). In addition, Tabata et al. (28) examined the effects of moderate-intensity training to vigorous-intensity training in young males, which resulted in an increase of 5 $mL \cdot kg^{-1} \cdot min^{-1}$ and 7 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively.

The variances in the extent of improvement for VO_2 max may be explained by the methodological differences between studies. The duration and intensity of the studies vary, which emphasizes the importance of the dose-response relationship for optimal change in VO_2 max. For example, it is not reasonable to compare a low-to-moderate intensity study to a vigorous-intensity study for the same duration of time. In long-term studies, there is evidence that high-intensity training elicits a greater increase in VO_2 max than low-intensity training for the same total energy expenditure (18,19). It has been suggested that the improvement in VO_2 max is dependent on intensity (18). This is supported by experimental data from Gormley et al. (12), who reported that VO_2 max significantly increased in the near maximal, vigorous and moderate intensity group by 7.2, 4.8, and 3.4 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. In addition, the percent increases between groups were all significantly different ($P<0.05$). The percent increases were 20.6%, 14.3%, and 10%, respectively.

The individualized exercise prescription approach has been found to be effective at eliciting improvements in VO_2 max for older and younger individuals in the current study and a few others. For instance, Wolpern et al. (35) compared the individualized approach of exercise prescription to standardized HRR and a control group among young individuals. The findings demonstrated a greater improvement in VO_2 max and body composition for the individualized program compared to the other two groups. Similarly, another studied compared the individualized approach to a standardized HRR and control group among older individuals (10). The study reported a more favorable increase in VO_2 max, body composition, and muscular fitness in the individualized prescription group. These studies, along with the current findings, highlight the efficacy of an individualized program, which may lessen the variability in metabolic responses of individuals across a large age range of individuals with varying fitness levels (10).

Muscular Fitness

Strength measurements among the younger and older groups improved significantly. For bench press 5-RM, there was an average increase of 4.3 kg or 13% in the younger group and an increase of 3.1 kg or 8.3% in the older group. Weiss et al. (33) found a significant improvement in bench press measurements after completing 7 wks of either a traditional resistance training program or a functional resistance training program. These younger individuals were able to increase their 1-RM by about 8 to 9 kg (33). In comparison, older individuals who participated in a 10-wk resistance training study demonstrated an increase of about 12 kg (4). It is likely that the differences can be explained by the sex difference and duration of each study. In the literature, there is evidence that males have more skeletal muscle compared to women with a greater difference in the upper body compared to the lower body (15). Duration of each study differed by 3 wks, thus suggesting a longer overload period in the older group that may have resulted in greater strength gains (25).

Measurements for leg press 5-RM were statistically significant in the younger group with a marked increase of 41.8 kg. The percent improvement was 37.6%. Although not significant, there was an increase of 21.2 kg, or 23.3%, in the older group. There is a greater rate of decline in lower body strength compared to upper body strength with aging (7,15). Therefore, older individuals may have a harder time improving muscular strength at the same rate as younger individuals. In addition, older individuals exhibit both muscle tissue atrophy and a loss of muscle fibers, particularly type II muscle fibers, also known as fast-twitch fibers (31). These declines result in the inability to generate strength rapidly (4). Furthermore, power declines at a faster rate than strength (7). Thus, the increases in lower body measurements are not surprising. These findings are comparable to other findings from the literature. In the study conducted by Bottaro et al. (4), individuals found an improvement in 1-RM by about 47 kg, which may be hard to relate to a 5-RM. The takeaway was that older individuals were able to improve lower body strength, but not at the same magnitude as younger individuals.

Body Composition

In addition to the decrease in muscle mass and muscular strength, there are age-related increases in the amount of adipose tissue with a marked increase in the accumulation of central body fat (7). Moderate-intensity training has been shown to decrease the amount of total body fat in middle-aged to older individuals with the magnitude of change being dependent on the frequency of the training sessions. It also appears that both aerobic and resistance training help attenuate the increase in total body fat that occurs with age (29). In the current study, body composition measures decreased significantly and comparably in the younger and older individuals by 4.8% and 5.8%, respectively.

Flexibility

Stretching was not directly implemented in the present study. The results indicate a greater change in the younger group compared to the older group. A plausible reason for the difference is the decrease in joint ROM with age, which may not have allowed for statistically significant improvements in low-back/hamstring flexibility. Measurements for sit and reach increased significantly in the younger group by approximately 6.6 cm, with older individuals improving favorably by 3.6 cm. The latter response by the older subjects was a positive outcome, although it was not significant.

Cardiometabolic Measures

Secondary outcomes were not statistically significant. However, it is important to highlight that the measurements were generally favorable for each variable. Mean FBG values remained very similar from the baseline to post-program in the younger subjects, which was expected considering that the values were within the normal range at baseline. The mean FBG values decreased slightly in the older group, which also was expected since there is an increase in insulin resistance with age (31). This leads to insufficient uptake of glucose with an increased secretion of insulin, which ultimately causes an increase in levels of blood glucose.

The current research study found improvements in HDL in the younger subjects. The younger group shifted into the desired range for HDL during the study; whereas, the older group was already in the desired range at baseline. The LDL levels decreased in the older group, which was a favorable outcome. However, the LDL in the younger group increased, which was an unfavorable outcome. Total cholesterol shifted favorably in the older group, yet shifted unfavorably in the younger group. Reasonably, this could be a result of the increase in HDL values, and increase in LDL values for the younger group. Nevertheless, post-program values for both groups were within desirable ranges for TC. The greatest improvement for both groups was seen in TRG levels. The younger subjects decreased TRG by 16 $mg \cdot dL^{-1}$ and the older subjects decreased TRG by 30 $mg \cdot dL^{-1}$. There was a decrease in systolic BP of 4 mmHg in the younger subjects and 6 mmHg in the older subjects. Additionally, there was a difference in diastolic pressure of 10 mmHg in the older group, while the younger group maintained a desirable pressure.

The meaningfulness behind each of these measures is explained in greater depth elsewhere (9). The expected change for FBG is approximately 6 $mg \cdot dL^{-1}$. The data in the current study does not follow this trend for the possible reasons explained earlier. The expected change for HDL is ~2 to 8 $mg \cdot dL^{-1}$, which was slightly above that range in the current study for the younger subjects. The 10 $mg \cdot dL^{-1}$ increase relates to a 20 to 30% decrease in the risk of a CHD event. The decrease in LDL was 7.9%, which is comparable to the expected 3 to 10% decrease. The 7.9% decrease translates to about an 8% decrease in the risk of a CHD event (9). Total cholesterol in the older group decreased 9%, which falls within the expected change of 4 to 20%. Therefore, the decrease in CVD risk was approximately 18% within the older group. In the literature, a 2 mmHg decrease has been suggested to decrease stroke mortality by 6% (9). Thus, the decrease in stroke mortality was 12% and 18% in younger and older subjects, respectively. The expected change for diastolic BP is a decrease of 2 mmHg, which was seen in the older group with a decrease of 4 mmHg over the 8 wks.

Limitations in this Study

There were some limitations in the current study that should be acknowledged. One such limitation was the sample size in comparison to other training studies. However, monitoring exercise was more feasible with fewer subjects. Additionally, dietary habits were not assessed and it is, therefore, unknown how dietary patterns may have influenced the results. Furthermore, the subjects' sedentary behavior and physical activity outside of the study were not monitored and may have impacted the outcome of the findings.

CONCLUSIONS

Overall, it is more than reasonable to conclude that the individualized exercise prescription approach was successful in positively impacting health-related components of physical fitness. Indeed, the older subjects were able to adapt to personalized cardiorespiratory and functional/resistance training and improve health-related components of physical fitness to the same relative extent as the younger subjects. However, the older subjects may have a harder time increasing their lower body strength to the same magnitude as the younger subjects. Future research is required to identify at what time point (if at all) younger and older individuals no longer share similar training adaptations.

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